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ABSTRACT

Reported are the discussions and votes on issues related to engineering education. Sections included are an introduction to the National Congress on Engineering Education and an overview of the meeting including 79 resolutions related to the four areas of broad-academic issues, faculty issues, curriculum issues, and issues on laboratories, computers, and educational technology; several major directions; and implementation. Appendices include presentations on: (1) "Engineering Education Answers the Challenge of the Future" (Nam P. Suh); (2) "Educating Engineers for the 21st Century" (Louis L. Guy); (3) "The Creative Mind and the Competitive Challenge" (Roland W. Schmitt); (4) "Curriculum Issues: A Summary and Overview" (Gene M. Nordby) (5) "Summary: National Congress on Engineering Education" (Leighton E. Sissom); (6) voting and resolutions; (7) voting statistics; (8) participant profiles; (9) resolution statistics; (10) references (76 items); (11) a list of participants; and (12) pre-congress packet of 70 pages. (YP)

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PROCEEDINGS

NCEE

NATIONAL CONGRESS ON ENGINEERING EDUCATION

November 20–22, 1986
L'Enfant Plaza Hotel
Washington, DC

Gene M. Nordby, *Chairman*
Russel C. Jones, *Co–chair, Program*
Gordon H. Geiger, *Co–chair, Program*
David R. Reyes–Guerra, *Secretary*

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INTRODUCTION

The National Congress on Engineering Education (NC2E), "Engineering Education Answers the Challenge of the Future", was an idea whose time had come when Dr. Nam P. Suh, Director for Engineering at the National Science Foundation (NSF) called a December 10–11, 1985 meeting of the leaders of the engineering profession to discuss different aspects of the Foundation's activity. Prior to that time, several meetings in which the major topic had been engineering education, with emphasis on a perceived crisis situation, had been held among the engineering leadership. Among them we can cite the yearly professional and technical society liaison activities of the National Society of Professional Engineers (NSPE) and the National Academy of Engineering (NAE), as well as the annual meeting of the Accreditation Board for Engineering and Technology (ABET) and its annual Industry/Government Symposium. The crisis in engineering education was a topic that ran through all of these meetings.

Dr. Gene M. Nordby, then President of ABET, suggested at the December 10–11, 1985 meeting that ABET, as the only federation of engineering societies dedicated exclusively to engineering education, should take the initiative and provide the leadership for a national action congress to address the many engineering education issues that have surfaced and that have been subjects of many reports and studies during the past 10 years. Unfortunately, all of these studies have not been thoroughly digested, and their implementation recommendations have not been weighed and prioritized. It was decided that such an action congress (later to be known as the National Congress on Engineering Education) should not be just another forum that produces a study but should be a source of leadership for the implementation of viable recommendations and actions addressed to the entire community served by engineering: the profession, industry, government, educational institutions, students, and the public.

NC2E was then organized with an Executive Committee composed of Dr. Nordby as Chairman, Drs. Russel C. Jones, Vice President for Academic Affairs at Boston University, and Gordon H. Geiger, Executive Vice President at North Star Steel Company, as Program Co-chairmen, and Dr. David R. Reyes-Guerra, ABET Executive Director, as Secretary.

Three major areas of concern were identified: Faculty Issues, Curriculum Issues (to include Broad Academic Issues), and Issues on Laboratories, Computers and Educational Technology, each to be addressed by a special committee. Chosen to chair the Major Issues Committees were: Dr. Lionel V. Baldwin, President of the National Technological University, to chair the committee on Laboratories, Computers and Educational Technology; Dr. Leroy S. (Skip) Fletcher, then President of the American Society of Mechanical Engineers, to chair the committee on Curriculum Issues; and Dr. Bruno O. Weinschel, President of the Institute of Electrical and Electronics Engineers, to chair the committee on Faculty Issues. The Major Issues Committees, whose memberships are shown elsewhere in this document, met and

developed the issues in the form of resolutions to be addressed by NC2E. Each committee had the material that appears in the bibliography as sources of reference.

The NC2E Program Review Committee, composed of members of the Major Issues Committees and representatives of each of the 23 ABET member societies and representatives of the National Science Foundation, met to further define the content of NC2E.

An Honorary Advisory Committee was created and included highly prominent and distinguished representatives of the publics served by engineering, such as the chief executive officers of major corporations, e.g., Hewlett–Packard and Amoco; members of Congress, e.g., Senator John D. Rockefeller, IV and Congressman Don Fuqua, plus members of the leading educational organizations in this country, such as the American Council on Education and the Association of American Colleges, as well as groups dedicated to industry, such as the Conference Board and the Business–Higher Education Forum. The Honorary Advisory Committee contributed significantly to NC2E by providing input and reviewing material.

NC2E was nationally announced through display advertisements in *The New York Times* and *USA Today*. These ads were geared toward attracting the input of the business and industrial sectors. All of the engineering societies were asked to announce NC2E, and many of them did so through their journals, newsletters, and other publications.

During the study phase by the Major Issues Committees, the need was noted to address some special issues which did not fit into the three areas already identified. Dr. Gene M. Nordby then undertook to handle this area, and the Broad Academic Issues were developed.

Approximately three weeks prior to NC2E itself, the 415 participants, as well as the engineering societies' leaders and the members of the Honorary Advisory and other NC2E committees, were sent a complete set of all of the resolutions that had been developed by the Major Issues Committees. This study document was the basis for the actions at NC2E. Arrangements were made so that those who could not attend the congress could give their input prior to the event.

OVERVIEW OF NC2E

The National Congress on Engineering Education was held on November 20–22, 1986 in Washington, DC. A total of 415 participants met to consider their positions and to discuss a series of resolutions that had been previously circulated. The participants then proceeded to vote on these resolutions and on others that were generated during the NC2E deliberations. A total of 79 resolutions in four areas were considered, such as:

BROAD-ACADEMIC ISSUES

> Encourage the first professional degree to be a 160 semester credit hour or five–year program, and prescribe this program by 1995 as the basic program that ABET will accredit.

> Reinstitute dual–level accreditation for those disciplinary fields that want it, so that both a baccalaureate and a masters at the same institution in the same discipline may be accredited.

> Define ideal program content to assist institutions in seeking higher quality goals.

FACULTY ISSUES

> Graduate fellowship at 1/2 salary of a B.S. graduate
> Reward faculty for ability and effectiveness in teaching
> Faculty must have a minimum of two years of practical experience
> Increase university–industry interaction
> Faculty must be competent in communication
> Faculty must professionally develop to maintain competence

CURRICULUM ISSUES

> Expansion of courses or of content to include:
    1) Interdisciplinary work;
    2) Electives to expand requirements in basic sciences;
    3) Increased mathematics in areas of statistics, probability and numerical analysis;
    4) Areas which affect the global economy, such as quality control, manufacturing, cost analysis, budgeting, etc.;
    5) Communication skills;
    6) Better approaches to teaching design.

> Restricting and eliminating marginal programs; not creating new schools or new Ph.D. programs.

> Increase admission requirements; demand better secondary school preparation.

> Support the NSF move to increase its engineering involvement.

> Support laboratory teaching.

ISSUES ON LABORATORIES, COMPUTERS, & EDUCATIONAL TECHNOLOGY

> Emphasize critical need for:

1) Enhanced laboratory experiences;
2) Life–long learning;
3) Computer education and training for both faculty and students;
4) Industrial practice knowledge and interaction for faculty.

> A very interesting statement on the philosophy that must be practiced in evaluating laboratories and new teaching methodologies.

At NC2E, each registrant was given a special package that contained a set of questionnaires. One section of the package allowed NC2E to obtain a professional profile of each participant; the other sections asked the participant for his/her position on each resolution on a five–item graded scale: Strongly Agree, Generally Agree, No Opinion, Generally Disagree, and Strongly Disagree. The questionnaires provided for additional comment on each resolution and for suggesting new resolutions. The questionnaire package was designed to assure the anonymity of the respondent.

Professional profiles were obtained from 302 of the 415 participants. The returned usable voting from the questionnaires totaled from a high of 273 on one resolution to a low of 166 on another, with an average of over 220 votes per individual resolution.

During NC2E, each major issue area was handled during its own four–hour plenary session. After discussing each resolution, the participants recorded their positions on the questionnaires.

New input and items that were not clearly defined during the plenary sessions were addressed again during a final, concluding session. These resolutions were treated in the manner described above and are identified by a letter preceding the resolution number.

Outstanding speakers gave inspiring talks on issues in engineering education and the crisis in education, "crisis" being a key word in the profession today. These were interspaced over the three days of the congress.

> Dr. Nam P. Suh, Director for Engineering of the National Science Foundation, spoke on "Engineering Education Answers the Challenge of the Future":

"...the engineer's education must bring the realities of the marketplace closer to the realm of technical solutions. Our ability to engineer and innovate will determine the outcome of our long–term industrial competitiveness."

"...we need to nurture more creativity on the part of our students...teach a firm base in fundamentals in engineering and science subjects, as well as design...develop the...ability to experiment...give our

engineers some basic knowledge about the real world..."

"Debunking this myth...that we can afford to wait because things will work out...is what I came here today to talk about."

"We cannot say we have taught design...by simply instituting a course in design. We must make design a pervasive notion in every one of our engineering courses. ...we must create a creative culture where design is on top of the engineering agenda just as analysis is."

"We must act now. And we can't make change unless we stop thinking that we can fix engineering curricula piecemeal."

> **Mr. Louis L. Guy, President of the American Academy of Environmental Engineers, titled his talk "Educating Engineers for the 21st Century":**

"...not enough for engineers to know how to do the thing right; we must also know what is the right thing to do..."

"...we can't escape the bald truths that (1) the current four–year B.S. degree does not provide the educational foundation to grow beyond technical specialties, and (2)...the current university...system emphasizes knowledge and research to the total exclusion of teaching engineering practice."

"...why not provide immediate access to the state professional license?..."

"...ABET should require that all programs with engineering titles at a university be submitted for accreditation, or none will be accredited..."

"...at least six years [of education] will be required for a practitioner in the 21st Century..."

"We must break free the position of engineering faculty within the university structure so that professors will be compensated at the level they deserve."

"...if we believe America needs these changes in engineering education...why not?"

"...the future of America in the 1990's, as well as in the next century, depends on its engineers."

> **Dr. Roland W. Schmitt, Senior Vice President at General Electric Company, spoke on "The Creative Mind and the Competitive Challenge":**

"...That question [Why are we behind in the competitive world?], in simple, raw terms, is 'Why do the Japanese beat us so often?'"

"...[The] Japanese...are preeminently successful in linking their research to markets..."

"...the environment can be enriched if we use the challenge of competitiveness as the rationale for the funding needed to relieve the pressures..."

"...universities must establish more interdisciplinary professorships."

"Although we do need more engineering researchers...the rest of our engineers--the vast majority--need to be trained less like researchers than they are today--and more like old-fashioned, practicing, dirt-under-the-fingernails engineers."

"We often treat everything as a research problem--a problem of creating the elegant, inventive solutions without adequate considerations of cost, manufacturability and quality."

"...reforms are needed, perhaps even some experiments with extensive redesign of engineering education."

"...we need to keep working on industry-university interaction."

"The objective is not to reduce the emphasis on learning the fundamentals of engineering but, rather, to ensure that the engineer knows how to use those fundamentals and is motivated to satisfy his customers and clients, not just himself and his technical colleagues."

"The link between the creative mind and the competitive challenge has two parts--maintaining and strengthening our ability to make great leaps of creativity, in which we still lead the world...and executing innovation with speed and efficiency where we have slipped."

"The new world economy, based on knowledge, training, and skill, is here."

> **And Dr. Gene M. Nordby, then President of ABET, gave an "Overview of Curriculum Issues":**

"...the effects of world competition and the global economy came...rather quickly as other countries found their niche in the marketplace...now the Nation is aware of this multifaceted problem...industry is making new and different demands on engineering education."

"...the essential bridge between the schools and the apparatus for research and development...is undergraduate education."

"Many think our engineering graduates are the best...ever produced, at least in their technical training. Nevertheless, considerable dissatisfaction is expressed by industry spokesmen about the lack of certain attributes..."

"...more liberal arts and humanities... cross-disciplinary technical studies... depth in the discipline...ability in design...exposure to business practice...exposure to industrial life...diversity..."

"...engineering schools are good at providing the basic foundation but cannot provide a polished engineer.

"...schools must decide what they are best at doing and defer to industry those things which they cannot do."

"...[schools] must look for efficiency...and eliminate redundant coverage."

"It appears that no-matter how much efficiency we bring to the four–year program, there is not enough time to do the things the university can do best for a truly professional engineering program."

"...the resolutions are formulated with a plan toward evolution rather than revolution."

> **Dr. Leighton E. Sissom, Dean of Engineering at Tennessee Technological University and Chairman of the Engineering Deans' Council – with over 240 members – was chosen to provide a summary at the conclusion of the Congress. Dr. Sissom as a witness to all the proceedings provided a significant contribution to the better understanding of what had transpired over a very concentrated and memorable two days:**

"To say that we are in a dynamic world would be an understatement...the likes of which we've never seen before. In some areas, engineering education is being led by industry–and in certain subsets–by foreign industry."

"As a result of this Congress, every segment of our profession now has a full agenda. It is incumbent upon us to begin the debates, to wrestle with the issues and to make a fine profession even better."

"...this Congress has been very healthy for engineering education. It will inevitably improve all of engineering. To admit our problems is to begin to solve them."

"We have heard an overwhelming call at this Congress for continued emphasis of engineering design. In my assessment of the proceedings of the past two days, engineering design has been the main character in this drama."

"It is design which distinguishes the engineer from the scientist. It is design which ties us to the marketplace, which gives vent to the creativity of our profession."

"...you have recommended that the need for broadening courses and for communication skills be examined and strengthened."

"...this Congress has called for: 1) tightening accreditation criteria to dry up weak programs; 2) a moratorium on new Ph.D. programs, and 3) a moratorium on new schools of engineering."

"...you have called for building more bridges between industry and academe..."

"Hands–on laboratories continue to be necessary for the engineering student. And the faculty member must remain central to effective lab experiences."

"...these efforts take time, and our curricula are crammed full."

"The current national studies are right. But how do we make the time for all of these worthy recommendations?"

"We've heard some arguments for extending the length of our programs which lead to the first professional degree. And some of us have lived through the great debates of recent years on this subject. But it may be time to debate again..."

"...with the possible exception of some isolated athletic programs, nothing at the academy builds better alumni support than effective teaching."

"[Faculties] should be viewed as a symphony with each person playing his/her own part in a superior way such that the faculty as a whole makes good music together."

"If faculty wants something to happen, it will, and vice versa. We will insist upon a mix of theory and practice."

"Faculties must interface more with their industrial counterparts..."

As previously mentioned a scale of five (5) terms was used for voting on the resolutions: 1) Strongly Agree, 2) Generally Agree, 3) No Opinion, 4) Generally Disagree, 5) Strongly Disagree. The basis for the analysis was the number of votes cast on a given resolution, and the results are presented as a percentage of that number. Due to rounding, not all percentages total exactly 100%.

No further analysis was performed on the resolutions that received a majority, either in agreement or disagreement (set at 55% or more by adding either the two agreement or disagreement options). Those issues that appeared to be troublesome (mostly a matter of language) were rewritten and presented anew for voting during the final, closing session. In this document, both the original and final versions are shown with their respective votes.

When considering the resolutions, care must be taken to determine their origins. Over 70 references were utilized, with most of the in-depth material generated through the American Society for Engineering Education's (ASEE) Quality in Engineering Education Project (QEEP) report; the Goals of Engineering Education study of ASEE; ABET's *Engineering Education: Aims and Goals for the Eighties*; the National Science Foundation's *Undergraduate Science, Mathematics and Engineering Education*; Proceedings of ABET's 1983-85 Annual Meetings, and the National Academy of Engineering's *Engineering Education and Practice in the United States*. Special Major Issues Committees analyzed the references and determined the resolutions that would be presented to NC2E. Thus, NC2E provided a distillation of several years of study and reporting by numerous groups consisting of many different publics. The concerns of the industrial sector are very much in evidence in the resolutions, as well as the concerns of educational institutions, educators, and the profession.

When considering the results of the voting and the profile of those who cast ballots (78% in education, but only 34% in teaching), the reader must bear in mind that the resolutions are not the product of the educational establishment; the original studies and reports that became NC2E resolutions came from a variety of sources. They are really a consensus of all possible publics. One may consider that the NC2E voting confirms or denies the acceptance of the resolutions by the participants whose profiles are strongly oriented toward education.

The analysis of the voting was done as a total of all participants and then further broken down by the participant profile. Thus, each resolution is analyzed based on the participants' areas of major function: Administration, Engineering Design and Production, Research/Development, and Teaching.

Two other major analyses were made. One breaks down the voting by participant's Area of Major Activity (Engineering Education, Engineering Practice, Engineering Policy, and Non-engineering); the other breaks down the voting by "other characteristics" (Licensed Professional Engineer, Officer of Engineering Society, Member of Professional Technical Society, Member of a Society Education Committee). Note that when reading the profile statistics, not all percentages in each major area total 100%. Many participants fall into more than one category.

The data accumulated during the congress has been analyzed and is being presented to all interested publics. ABET urges engineering professionals, engineering societies, educational institutions, and industrial and government groups to seek implementation of the resolutions that fall within their purviews. NC2E will be successful only if the generated resolutions become bases for action.

As soon as is practicable, ABET will implement all resolutions that affect its area of primary concern: the accreditation of engineering, engineering technology, and engineering–related programs.

Apart from the major contributions of all participants, including the various committee members and others who independently provided their input to NC2E, several organizations lent substantial support by providing funding. These organizations are ABET, the National Science Foundation, the Engineering Foundation, the General Electric Foundation, IBM Corporation, the Amoco Foundation, and Exxon Engineering and Research Foundation. ABET and the engineering education community express their appreciation to these organizations for their contributions to the future of the country and the profession.

PARTICIPANT PROFILE ANALYSIS

The NC2E participants were skewed toward engineering education (78%), almost all male, and in the 40–to–60 age bracket (73%). Eighty percent (80%) are members of professional/technical societies. As expected, a large number of the participants have as their major functions supervisory positions as administrators (57%) or managers (52%), with responsibilities for supervising engineers (70%).

A significant number (63%) are licensed professional engineers with an earned doctorate (78%), working at an educational institution (75%). Curiously, only a small number (34%) are actually teaching.

The distribution of specialty areas is as expected in any cross–section of the profession, with the largest percentages in Civil, Electrical, and Mechanical Engineering (21%, 23%, and 28%, respectively).

There was a small but significant number of participants in engineering practice (16%).

Thus, even if the total was strongly representative of education, there was sufficient strength from other areas, so that the discussions, opinions, and voting were fairly well balanced between education and practice.

MAJOR DIRECTIONS SET

Analysis of the balloting by the participants at the National Congress on Engineering Education indicates several major directions which the profession should be pursuing at this point in time. These major directions, which will be discussed in some detail in this section, are the following:

- The current undergraduate curriculum needs to be updated.
- The engineering faculty need to be strengthened in a variety of ways.

- Engineering education needs more interaction with engineering practice.
- Educational technology should be utilized better by engineering schools.
- Longer programs of study in engineering should be facilitated, but not mandated.
- The profession should not attempt to limit schools wishing to develop new programs.
- Very broad agreement on a number of overarching issues, such as the need to help restore economic competitiveness to the United States.

Each of these major directions is supported by balloting on related resolutions. An analysis of that balloting follows:

Update the Undergraduate Curriculum

In a series of resolutions on the current undergraduate curriculum for engineering students, significant directions for updating were recommended by the participants in the congress.

The participants voted overwhelmingly (93%) for revision of the accreditation criteria in the mathematics area, recommending that students have more concentration in probability, statistics and numerical analysis. They also strongly supported (78%) a resolution recommending that the accreditation criteria for basic science should be expanded to give more breadth in preparing students for such application areas as biotechnology, information sciences, geotechnology and advanced materials. Even stronger support (91%) was evidenced for a resolution encouraging ABET to intensify its effort on design, innovation and creativity requirements in engineering programs. It was noted that such programs should continue to include considerations of economic factors, safety, reliability, aesthetics, ethics, and social impact.

The liberal arts and humanities component of engineering education was supported (77%) for expansion and optimization. ABET was encouraged to see that the humanities/social sciences requirement is more carefully administered, and engineering schools are encouraged to work with their liberal studies faculties in the design of core sequences to utilize the available time for this study more effectively. Engineering faculty were also encouraged (71%) to take the initiative in building the communications skills of their students in reading, speaking and writing.

Several new requirements for undergraduate curricula were also supported by the participants in the congress. A large majority (90%) supported the recommendation that engineering curricula should be strengthened so as to require institutions to demonstrate that computer use is an effective part of the instructional

program. Substantial support (67%) was also evidenced for making statistics, particularly as applied in experimental design and quality measurement, an integral part of every engineering program. In the area of health and safety, 69% of the participants supported the strengthening of existing courses to include practical instruction on responsibilities in safety, health, product liability, and reliability. Overwhelming support (91%) was also recorded for a resolution that recommended the introduction of educational technologies such as instructional television and combinations of television and computers to undergraduates in order to prepare them for a lifetime of continuing education.

There was considerable support for inclusion in the undergraduate curriculum of more elements of the real world of engineering practice. Some 80% of the participants in the congress supported a resolution that would require interdisciplinary coursework to focus on the solution of engineering problems in the manufacturing and construction areas. Such coursework would focus on the integration of design, planning, simulation and control. A majority of the participants (79%) also felt that engineering programs should include study of topics important in the industrial environment, such as engineering cost analysis, project management and organization, resource budgeting, and leadership theory and practice. At a broader scale, 67% of the participants supported a resolution which would place an emphasis on technical areas which strongly impact the competitive posture of the United States in all foreign markets. Such areas might include robotics, manufacturing processes, microcomputers, statistics, quality control, and inspection.

In addition to examining the undergraduate curriculum in the considerable detail indicated by the resolutions described above, the participants in the congress also briefly turned their attention to the question of input to the engineering schools from secondary education. A substantial majority (73%) supported a recommendation that college of engineering admission standards be set at a level that would require adequate secondary school preparation in science, mathematics, and verbal skills, such that college remediation in these subject areas would not be required. Mastery of the English language was additionally singled out as a requirement for admission to an engineering program, with 67% of the participants supporting a strong requirement.

Strengthened Faculty

Strong support (73%) was evidenced for the need to increase the attractiveness of graduate programs, in order to build up the flow of postgraduate students who might later select faculty careers. An even higher percentage of the participants (89%) supported a resolution which recommended that the stipends for doctoral fellowships be set at a level at least half of the starting salary of a new B.S. graduate. It was felt that this major increase in support was needed to attract more of the very brightest U.S. citizens into graduate programs in engineering.

A series of resolutions dealt with new or additional requirements for engineering faculty members. Those which received significant support were:

- Proficiency in English should be required of all teaching assistants and new faculty members for whom English is a second language (86% agree).

- Engineering faculty should have accumulated a minimum of two years of experience in engineering practice before senior faculty status is attained (75% agree).

- There should be clear evidence of ability and effectiveness in teaching before tenure is granted to an engineering faculty member (90% agree).

- Workshops in effective teaching should be conducted by engineering schools to provide guidance and assistance for both new and continuing faculty members, including adjunct or part–time faculty (87% agree).

- Engineering faculty members must stay current with their technical fields and with educational developments, thus maintaining their professional competence (76% agree).

- Balanced composition of the faculty members in engineering departments is encouraged, where in addition to teaching, the following areas should be addressed: science, engineering practice, design analysis, strong professional experience, and research (84% support).

- The quality of life of engineering faculty members must be improved, in order that the very best engineering students are attracted to future faculty positions; such improvement can be effected by limiting teaching loads to reasonable levels, providing the faculty with time for library and computer studies, providing modern facilities, and competitive compensation (89% support).

- It was further recommended that the accreditation requirements for number of faculty members be increased to provide adequate numbers of faculty for instruction and laboratory coursework (73% agreement).

- Some faculty members should be selected on the basis of education for professional competence and engineering practice, in order to recruit and appropriately develop professionally competent graduate students (73% agreement).

- Schools that emphasize undergraduate education can utilize many faculty who do not have doctoral degrees (85% agreement).

- ABET should carefully monitor the university environment within which engineering education occurs. Among other things, institutions should be encouraged to seek a proper balance between teaching, research and service in their tenure and promotion criteria, keeping in mind the needs of the profession as expressed by industry, professional societies, and society at large (76% agree).

More Interaction with Practice

Several resolutions recommended much stronger interaction between engineering education and the practice of the profession. Several of the resolutions noted above in the curriculum and faculty areas already point in that direction. Additional resolutions, described below, also emphasize the desirability for increased educator–practitioner interaction.

A recommendation that an advisory committee of practicing engineers be mandated in each engineering educational unit received strong support (75%). Participants in the congress also strongly endorsed increased emphasis on advanced development in university research projects, where such projects are cooperatively sponsored and jointly administered by industry and government agencies (90% agreement). It was felt that such projects would enhance the university–industry interaction and should also contribute to curriculum and faculty development.

The participants were asked whether ABET should continue its efforts in developing programs to assist the quality of continuing education programs. Sixty–five percent of the respondents encouraged ABET to proceed in this direction, as a way of assisting practicing engineers in assessing the long–term benefits and effectiveness of continuing education programs.

Utilize Educational Technology Better

The participants in the congress agreed with a series of background resolutions on the appropriate role of technology in engineering education:

- The teacher must continue to be the primary focus in education, but today's technology should be used to enhance the teaching process (98%).

- Laboratory experience is a vital component of engineering education, and should be included in every undergraduate engineering program (100%).

- The conventional library, enhanced by the collection, delivery and processing of information using today's technology, must be made available to today's students (96%).

The participants also broadly supported a series of background resolutions on resource allocations in the area of use educational technology:

- Industry was urged to continue its financial support for laboratory and computing equipment, through contribution programs (97%).
- Cooperative efforts need to be made to develop new approaches for maintenance of computer hardware and software (92%).
- Efforts should be made to acquire laboratory equipment through industry donations, similar to the successful efforts recently experienced in the computer area (90%).
- Efforts should be made to improve regional sharing of major experimental facilities between universities (51%).
- Industry should make technician training available as part of equipment donation packages.

The congress participants also reviewed proposed accreditation guidelines and criteria in the areas of laboratory and computer utilization. Strong support (79%) was evidenced for ABET criteria which would encourage and reward faculty members for providing dynamic laboratory experiences, and would assure faculty members adequate time to fully plan and prepare laboratory instruction. A similar resolution in the computer area, suggesting that ABET should examine the commitment of engineering programs to the encouragement and reward of faculty members to integrate the computer into coursework in an innovative and dynamic manner, with adequate time provided, also obtained significant support from the conference participants. (78%).

The task committee working in advance of the congress on laboratories, computers and educational technology drafted a "Strawman" of ABET criteria for laboratory and computer experience. While that particular draft did not receive overwhelming support from the congress participants, a general charge that ABET should proceed to develop more specific criteria in this area was well supported (71%).

Facilitate Longer Programs

Perhaps the most difficult area with which the congress wrestled was the area of length of engineering education for the entry of graduates into professional practice. In his prepared comments distributed to the congress, ABET President Gene Nordby concluded:

> "It appears that no matter how much efficiency we bring to the four-year program, there is not enough time to do the things the university can do best for a truly professional engineering program.

Although a five-year program may not be long enough to teach everything needed, it would be a start."

The congress was then offered a series of resolutions concerning length of the basic engineering educational package. After an iteration of rewriting during the course of the congress, two resolutions received marginal support:

- The proposal that a five-year program will be necessary to provide sufficient breadth and depth in engineering education to qualify for entry to an engineering career at the professional level was agreed to by 49% of the participants at the congress, and disagreed with by 47% of the participants.

- The facilitating resolution which would allow institutions to experiment with longer programs while maintaining current four-year efforts, that is, that ABET should reinstitute dual-level accreditation to encourage a longer period of study in a transitional era, was agreed to by 49% of the participants and disagreed with by 43% of those present.

More focused recommendations for changing the current pattern of four-year undergraduate education for entry to the profession were not well received:

- A proposal which would have prescribed a five-year program by 1995 was disagreed with by 61% of the participants.

- A proposal which would have reduced the technical content of current four-year programs in order to make room for broader educational topics was disagreed with by 66% of the participants.

- A proposal to study whether an even longer period of study would be desirable, such as a four-year pre-engineering program followed by three years of post-baccalaureate work leading to a doctorate in engineering as the first professional degree, was disagreed with by 55% of the participants.

<u>No Limits on Schools</u>

The participants in the congress were offered a series of resolutions which would have limited the prerogatives of schools in a variety of ways, while perhaps improving the overall situation for engineering education. Each of these attempts was less than enthusiastically received by the conference participants:

- One resolution recommended that minimum accreditation requirements be raised in order to increase the quality of programs and their graduates, in the process eliminating marginal programs or forcing

them to get the resources needed to improve them. This resolution was supported by 52% of the participants, and opposed by 39%.

- The participants were asked whether engineering schools with limited resources, which have a primary orientation to undergraduate education, should be encouraged not to institute new Ph.D. programs and where such programs are already in place to eliminate small doctoral efforts. This resolution was supported by only 37% of the participants, and opposed by 59%.

- Recognizing the shortage of qualified engineering faculty and limited resources to maintain facilities, the participants were asked to recommend that a moratorium be declared on the creation of additional schools of engineering. This resolution again failed to glean support, with 41% of the participants agreeing with it, but 53% disagreeing.

Another series of resolutions explored potential additional parameters which the accreditation process might check at universities. These also failed to gain support from the congress:

- A recommendation that faculty members who teach design related to safety and protection of the public be registered professional engineers was supported by 46% of the participants, but opposed by 51%.

- A recommendation that each discipline develop an ideal model program and offer this as guidance to educational institutions as a direction for quality was supported by only 37% of the participants, and opposed by 57%.

- A recommendation that ABET review engineering school efforts to increase the enrollment, retention, academic performance and graduation rate of minorities and women was supported by 47% of the participants, but also opposed by 47%.

By rebuffing this series of resolutions, the participants in the congress clearly drew a line between those areas where the profession should take an active role in monitoring engineering education (the curricula, faculty, and educational technology sections above) and those where the schools should retain their own prerogatives (quality standards, new schools, new graduate programs, etc.).

Consensus Statements

There were a series of broad issues on which the participants in the congress indicated broad consensus support. These included:

- Major resources should be provided to the engineering educational enterprise in order to restore economic competitiveness to the United States in the international arena (93% agreement).

- Support was evidenced for the National Science Board initiative at substantially increasing funds available for undergraduate engineering and science education (87% agreement).

- As noted above in the section on educational technology, broad support was evidenced for using technology to enhance faculty members' presence in the classroom and laboratory, to keep laboratories and information sources central in undergraduate education, and to keep up the mechanisms for industry donations of equipment.

DETAILED ANALYSIS

The exact language of each resolution considered at the congress is shown in Appendix B, along with the overall results of voting by the participants. The resolutions are grouped into the categories within which they were presented in plenary sessions at the congress:

- Broad Academic Issues

- Curriculum Issues

- Faculty Issues

- Issues on Laboratories, Computers and Educational Technology

Within each section, any resolution which was revised during the congress appears twice--with revised wording and later vote on that wording appearing at the end of the section.

An overall summary of participant votes is contained in Appendix C. The votes in each of the five rankings (from Strongly Agree to Strongly Disagree) are also shown graphically in this appendix.

More detailed analysis of the participant votes, cross-tabulated with certain key characteristics of the individual participants, are contained in Appendix D. Statistics are broken down by:

- Major function (Administration, Engineering Design and Production, Research/Development, Teaching)

- Major activity (Engineering Education, Engineering Practice, Engineering Policy, Non-engineering)

- Other characteristics - (Licensed Professional Engineer, Officer of Engineering Society, Member of Professional/Technical Society, Member of Society Education Committee)

and are presented in both tabular and graphical form.

IMPLEMENTATION

The National Congress on Engineering Education developed and considered resolutions which should have impact across many organizations concerned with the engineering profession and engineering education. In order to call each resolution to the attention of the appropriate organizations for follow-up and implementation, the following table has been developed. Primary responsibility for implementation is assigned to each of the following organizations in this table:

- Accreditation Board for Engineering and Technology
- National Science Foundation
- Educational Institutions
- Professional/Technical Societies
- Industry
- Government

In many cases, responsibility for appropriate follow-up is shared by more than one organization.

PRIMARY RESPONSIBILITY FOR IMPLEMENTATION

	ABET	NSF	INSTITU-TIONS	PROF/TECH SOCIETIES	INDUSTRY	GOVERN-MENT
FACULTY RESOLUTIONS						
1. GRADUATE PROGRAM ATTRACTIVENESS			X			
2. GRADUATE SUPPORT		X	X		X	
3. PROFICIENCY IN ENGLISH			X			
4. THE TEACHING FUNCTION			X			
5. TEACHING WORKSHOPS	X		X			
6. ENGINEERING PRACTICE	X		X		X	
7. BALANCED DEPARTMENTS			X	X		
8. FACULTY CAREER ATTRACTIVENESS	X		X			
9. PROFESSIONAL COMPETENCE	X	X	X	X	X	
10. INTERACTION WITH INDUSTRY			X		X	
11. UTILIZE FACULTY W/O DOCTORATES	X		X		X	
A1. GRADUATE PROGRAM ATTRACTIVENESS			X	X	X	
A2. PROFICIENCY IN ENGLISH	X		X			
A3. PROFESSIONAL COMPETENCE	X	X	X	X	X	
A4. UTILIZE FACULTY W/O DOCTORATES	X		X		X	
CURRICULUM ISSUES						
1. COMPUTER USE	X	X	X		X	
2. MANUFACTURING & CONSTRUCTION	X	X	X	X	X	
3. BASIC SCIENCE REQUIREMENT	X		X	X		
4. MATHEMATICS REQUIREMENT	X	X				
5. THE GLOBAL ECONOMY	X	X	X	X	X	X
6. THE INDUSTRIAL ENVIRONMENT			X		X	
7. ENGINEERING SCIENCE CRITERIA	X			X		
8. BASIC EDUCATION REQUIREMENT	X		X	X		
9. ENGINEERING DESIGN CRITERIA	X	X	X		X	
10. LIBERAL ARTS & HUMANITIES			X			
11. INTERNATIONAL ACCREDITATION	X					
12. PROFESSIONAL-LEVEL ACCREDITATION	X			X		
13. ACADEMIC PROGRAM LENGTH						
III. REINSTITUTE DUAL LEVEL	X			X		
14. REQUIRE STATISTICS	X			X		
15. HEALTH & SAFETY	X			X		
17. REQUIRE ORIENTAL LANGUAGES						
B1. INTERNATIONAL ACCREDITATION	X			X		
B2. PROFESSIONAL-LEVEL ACCREDITATION	X					
B3. REQUIRE STATISTICS	X			X	X	
B4. HEALTH & SAFETY				X	X	
B6. MASTERY OF ENGLISH REQUIREMENT			X			
B8. ENCOURAGE 5-YEAR PROGRAM	X	X	X	X	X	
B9. REINSTITUTE DUAL LEVEL ACCRED.	X			X		
BROAD ACADEMIC ISSUES						
2. MORATORIUM ON PhD PROGRAMS			X			
3. MORATORIUM ON NEW SCHOOLS			X	X		
4. FACULTY & LAB REQUIREMENTS	X			X		
5. ADMISSIONS REQUIREMENTS			X			X
6. REGISTRATION FOR TEACHING			X	X		
7. ADVISORY COMMITTEES	X		X			
8. QUALITY GOALS				X		
9. UNIVERSITY ENVIRONMENT	X	X	X	X	X	X
10. CONTINUING EDUCATION	X	X	X	X	X	X

	ABET	NSF	INSTITU-TIONS	PROF/TECH SOCIETIES	INDUSTRY	GOVERN-MENT
BROAD ACADEMIC ISSUES, CONT'D						
11. COMPETITIVENESS		X			X	
12. NATIONAL SCIENCE BOARD	X	X	X	X	X	X
D1. LIMITING PROGRAMS	X			X		
D4. REGISTRATION FOR TEACHING	X		X			
D6. CONTINUING EDUCATION	X	X		X	X	
D7. MINORITIES & WOMEN	X					
D8. DR. OF ENG. AS 1st PROFESSIONAL DEGREE	X			X		
LABORATORY, COMPUTER AND EDUCATIONAL TECHNOLOGY ISSUES						
ROLE OF TECHNOLOGY						
1. FOCUS ON TEACHING			X			
2. LABORATORY EXPERIENCE		X	X			
3. LIBRARY			X			
4. LIFE-LONG LEARNING	X	X	X	X	X	X
RESOURCE ALLOCATIONS						
1. INDUSTRY FINANCIAL SUPPORT					X	
2. COMPUTER MAINTENANCE			X		X	
3. DONATED EQUIPMENT					X	
4. UTILIZE REGIONAL LABORATORIES			X		X	X
5. TECH. STAFF TRAINED BY INDUSTRY					X	
ACCREDITATION CRITERIA						
1. LABORATORY REQUIREMENT			X			
2. COMPUTER REQUIREMENT			X			
3. "STRAWMAN" CRITERIA	X	X	X	X	X	X
C1. SPECIFIC CRITERIA	X			X		

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APPENDIX A

Keynote Presentations

ENGINEERING EDUCATION ANSWERS THE CHALLENGE OF THE FUTURE

NATIONAL CONGRESS ON ENGINEERING EDUCATION

WASHINGTON, DC

NOVEMBER 20, 1986

REMARKS BY DR. NAM P. SUH

ASSISTANT DIRECTOR FOR ENGINEERING

NATIONAL SCIENCE FOUNDATION

Introduction

Thank you for your warm words of introduction. It is indeed a pleasure to be here with all of you today. I can say without any sense of exaggeration that the theme of this program -- "ENGINEERING EDUCATION ANSWERS THE CHALLENGE OF THE FUTURE" -- is one of the most critical issues facing this nation today. I appreciate the opportunity to talk about this issue. I would like to thank Dr. Gene Nordby for the invitation. I think I speak for all of us here when I say that we appreciate the leadership of the organizers of this meeting, particularly Gene Nordby.

Before I address today's subject, let me make some rather personal remarks. First of all, I am very proud of being a member of this engineering education community. You have accomplished a great deal in the past in establishing strong engineering educational programs. I am one of the beneficiaries of the strong engineering base the engineering education community as created. Thanks to you, our engineering schools in the U.S. are far superior to any I know of in the world. And yet you are gathered here seeking an even higher plateau for engineering education. Your action bodes well for the future of this nation. In this spirit let me raise a few issues.

In his just released and highly acclaimed book, *The Cycles of American History*, Arthur Schlesinger, Jr. states that "Science and Technology revolutionize our lives, but memory, tradition and myth frame our response." Memory...tradition...myth. The words never seemed so appropriate as they do today when we look at this nation's response to the challenges placed before us by our waning economic competitiveness.

We have fond "memories" our our international preeminence in science and technology. In the past, when we looked at our total national investment in research and development and saw that it exceeded the combined investment of our major industrial competitors, we felt satisfied. When we looked at the number of scientists and engineers that we employed and their contribution to the pool of the world's scientific literature, we felt satisfied. And when we added up our Nobel

prizes in science and found they exceeded those of all other countries combined, we felt satisfied.

It has only been within the last few years, however, that we have begun to understand that we can't live on memories. What we took for satisfaction can now be considered complacency. We now know we will no longer be in a position to dominate each and every field of scientific endeavor. Nor will we hold a monopoly on the world's supply of scientific and engineering talent. Other nations have established strong national programs in science and technology. We will not get very far in the battle of international competitiveness by sitting on our memories.

"Tradition" also framed our nation's response in the past when we tried to nurture scientific and technological advances. We were guided by a view that for the engineering infrastructure to be strong in this country the major emphasis had to be on analysis, engineering sciences, and traditional engineering disciplines. Only recently have we come to understand that although that view has served us well in the past, we now must have a proper balance between analysis and synthesis, between analysis and experimentation, between cross-disciplinary research and single-investigator research, and between research in traditional engineering sciences and emerging engineering fields. We must continue this break with tradition, particularly as it applies to strengthening engineering design and cross-disciplinary research.

We cannot say we have taught design to our students by simply instituting a course in design. We must make design a pervasive notion in every one of our engineering courses. In other words, we must create a culture where design is on top of the engineering agenda just as analysis is.

The same comments apply to cross-disciplinary research. To be sure, the fact that researchers from different disciplines are working together on common problems is not new. But the breadth of their work is new -- and so is its importance. Collaboration across disciplinary boundaries -- collaboration in education as well as research -- needs strong nurturing and will require flexibility in attitudes as well as new organizational forms. A reliance on tradition -- "Business as usual" -- just won't do.

And now we come to "myth". Perhaps this is the most difficult to contend with. For one of our most established myths is that things will work out in the long run if we only give them a chance. Such a myth is, I believe, a prescription for inaction. It is a prescription for inaction at a time when scientific and technological advances are, we are told, outdated within five years. It is a prescription for inaction at a time when we are showing our first annual deficit in high-technology trade. And it is a prescription for inaction at a time when we must now lay the plans for moving into the 21st century -- a century which President Reagan calls the Pacific Rim era and when we shall see by the year 2000 the Western Pacific countries alone generate one-quarter of the world's gross national product.

Debunking this myth...this myth that we can afford to wait because things will work out...is what I came here today to talk about. Debunking this myth means becoming proactive, and no longer just reactive. It means moving from studies to stances; criticisms to coalitions; anxiety to action.

Why Now?

The time is right for such an effort. Why? Last year I stopped counting at 17 the number of major studies on competitiveness -- and that was the number put out just since 1982! The studies were important; I don't want to underestimate their significance. But those studies were done at a time when the competitiveness issue began as a debate over "industrial policy". The main focus was on saving the older, basic industries in the Rust Bowl.

But things have changed in just a year or so. The fall-out from the semiconductor pact, which threatens to make Silicon Valley our next Rust Bowl, is just one of the reasons for our concern. Whatever the others, the competitiveness theme is now supported by leaders of major universities, prominent technology companies, and some healthy corporations that aren't directly threatened by imports.

And most importantly, perhaps, the theme now appears to be on the verge of being made a major issue by the Cabinet-level Economic Policy Council. Just two weeks ago it was widely reported that the Council is considering a series of recommendations to be included in the President's State of the Union Address early next year. As reported in the press, one of the major recommendations being considered is how we revitalize the nation's educational system and the role that system plays in bolstering our competitiveness.

Time to Act

With these events and others -- such as the recently released Carnegie report on the inadequacies of undergraduate education in the United States -- you can see that we meet at a crossroads in our nation's history. That's why I say the time is right for action. And we need a prescription for that action.

What should this prescription for action be? I have read the material developed by the Major Issues Committees for this program. It is right on target. Let me offer a few comments and see what you think.

Engineering Environment

To develop this prescription for action we must ask ourselves several questions -- and then provide some answers. The first question is : <u>What is the environment in which our future engineers will be operating, and also what should be the thrust in the education of those engineers?</u> Engineering education for the 21st

Century must come to grips with a basic fundamental challenge: that engineers must be able to engineer and innovate to be competitive internationally.

To engineer, one must have a firm foundation in scientific principles and, perhaps more importantly, the ability to think and the ability to design engineering solutions.

To innovate means much more than simply solving problems others present. It means, first of all, the ability to define the problem that needs to be solved and coming up with a rational solution that the market place or the society needs. Innovation is, as Donald Frey, Chairman and Chief Executive Officer at Bell & Howell, has said,..."Innovation is both an extensive and intensive process." In short, the engineer's education must bring the realities of the market place closer to the realm of technical solutions. Our ability to engineer and innovate will determine the outcome of our long-term industrial competitiveness.

Learning this lesson is critical for deciding what we want to do. And the importance of it is not lost on our competitors either. For example, as the recent annual report of Japan's Economic Planning Agency observed: "Technological innovations are the prime movers of economic restructuring and the breakthrough factor for industrial development.

In addition to this need to thrive in the heightened internationally competitive world of the 21st Century, our future engineers are likely to find themselves in an environment where the use of new materials and materials-related issues will determine engineers' ability to engineer. What hinders the progress of electrical engineering and other engineering fields may be materials, both the availability of materials and our ability to engineer these materials for effective use.

Our future engineers may also find that to be a leading engineer in the 21st Century one must be comfortable with both the world of nature and the world of information. Major innovations in engineering will come when we can amalgamate two hitherto separate worlds: the physical world governed by the laws of nature and the information world. The education of an engineer is incomplete unless this symbiosis is clearly drawn.

And again, we cannot need overemphasize the importance of design in engineering which is a time invariant requirement of engineering. The engineer must understand the rational design, both for the manufacturing world and the information world. Exposure to the basic knowledge which undergirds all manufacturing...yes. But exposure to product development, quality control, marketing and distribution also.

Educational Emphases

The second question we must ask ourselves is: What do we need to strengthen in an engineer's education? First we need to nurture more creativity on

the part of our students. Creativity means the ability to synthesize new solutions in the absence of prior examples or paradigms. In order to be creative, they must learn how to define the problem by extracting the essence of the problem from a set of undigested facts and observations. By emphasizing the creative aspect of engineering, we can make engineering education fun, rewarding and interesting.

We also need to teach a firm base in fundamentals in engineering and science subjects, as well as in such subjects as design. At the same time, the student must be given a broad knowledge base so that the student will be given more than a vocational education. The student must acquire the ability to broaden his or her perspectives throughout his or her lifetime. The student must have a sense of history, for we are all victims and beneficiaries of history.

We need to develop the student's ability to experiment, since engineering still depends heavily on our ability to learn from experimental observations.

And we need to give our engineers some basic knowledge about the real world they will be operating in, such as industrial dynamics and the required communications skills, so that they can become more effective contributors to all aspects of industrial endeavors and ultimately become captains of industry in addition to being super technologists.

Engineering Needs

We now come to the final question -- and maybe the most difficult: What needs to be done? The material we received from the Major Issues Committees has many themes, but the one that is overriding is the theme of change. If there is one word that characterizes virtually all the material it is that cultural change -- and something more than just an incremental change -- is necessary.

And this means that we should effect a change not only in our universities, but also a change in industry -- which should use our engineers more effectively and become more directly involved in educating our engineers throughout their lifetime; a change in government -- not just in the Federal establishment but at all levels; and a change in society -- a change in people's perceptions of engineers and engineering.

To make these changes, however, means making changes in all areas.

Change can't come in the university if there is an exclusivity on traditional disciplines.

Change can't come in industry if all it does is view academe as a place from which to get some research results and hire graduates.

Change can't come in government if policymakers and government officials don't hear more directly from engineers about, among other things, the development

and use of emerging technologies and other contributions of the engineering profession;

And change can't come in society if all we do here is attract momentary attention, draft some recommendations...and then go back home and wait for things to happen.

We must act now. And we can't make changes unless we stop thinking that we can fix engineering curricula piecemeal. We should not be satisfied by, as I said, simply introducing a new design course. Rather, the entire framework which undergirds the engineering curricula needs to be analyzed. Each course needs to be reexamined for its contribution; the laboratory experience needs to be expanded significantly; the use of computers should be carefully introduced; and heavier doses of the arts and humanities added. When this is accomplished the sum should in fact be greater than the parts.

As we try to come up with an engineering curriculum that meets all the aforementioned elements of engineering education, I think it will be a mistake to just look at the number and content of required courses. The least creative solution to our engineering education is simply adding new courses to what we already have. We must create a learning environment where some of these things are more or less naturally absorbed by students because of the prevailing culture in our engineering schools. That means, a university culture in which learning takes place outside of classrooms as well as inside because students and faculty are seriously engaged in solving important problems of our era. Perhaps the number of required courses should be reduced to a minimum and let the student learn by working on real problems and from short learning modules that supply specific knowledge.

Consequences

Whatever we decide, if we don't take bold action now we will eventually see all our manufacturing jobs move overseas, with our engineering jobs close behind. When this happens our industrial infrastructure will be dismantled, our socio-economic system will be challenged, and our quality of life will deteriorate. Further, the ramifications will be felt globally: As we, the world's largest buyer and seller, contract our growth, so will the rest of the world.

And we will have only ourselves to blame for our failure. Our depth in human resources, capital and the dynamism of our market system are unequaled anywhere in the world. Further, the sheer magnitude of our home market gives us a powerful advantage. Our greatest edge is the relative freedom from the myriad rigid restrictions from which many of our foreign rivals suffer, and our socio-political environment which allows us to adapt more quickly and drastically to changing circumstances.

The Engineering Directorate of the National Science Foundation will do its part in this challenge. We understand that responding to the needs of engineering

education cannot work unless we become full partners in the effort. But we also understand that engineering education is a $3 billion enterprise. NSF has only limited resources. One of our major roles must be that of a catalyst, and then stepping back to let other initiatives carry on.

We have already undertaken important efforts and programs, such as those involving neuroengineering, computational engineering, engineering systems research in oceans, power, transportation and water, and many others. The most interesting information to you may be that NSF will be spending $9 million this year for undergraduate education, with $2.2 million for engineering education. Part of this Engineering fund will be used to initiate Creative Awards in engineering, which are designed to change the undergraduate culture by encouraging the involvement of undergraduates in the creative aspect of engineering.

In closing, let me ask you what is your vision of an ideal engineer and the requisite engineering education? What is your prescription for improving the quality of life through engineering? What kinds of your former students will make you proud of your hand in shaping their minds?

In answering these questions it is not good enough for you to deliberate and produce good reports. You must produce ideas that can be implemented by the Administration, Congress, universities and industry. You have my promise that I will work with you in making sure that your good ideas do not simply sit on somebody's bookshelf.

Let's work together.

EDUCATING ENGINEERS FOR THE 21ST CENTURY

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This meeting is exciting! Dynamic change is in the air. For those of us present, this carries with it a tremendous responsibility. We must, to the best of our abilities, assure that the changes which are charted in the system of engineering education are truly responsive to the needs of our nation. Although it is the current situation, and the problems we face in 1986, that has brought about this "Congress" to consider improvements, we cannot allow this opportunity to be wasted on meeting only short-term needs. To coin a phrase, we must avoid the "MBA Syndrome". Let us resolve that we will take full advantage of this time of changing direction, and that we will look ahead into the 21st Century as we discuss and debate how to shape engineering education for the future.

But, as any Virginian can tell you, the future is built on the past. Let me reflect on some lessons I have learned in twenty-five years of practicing engineering. We need to understand where we are today, before we can discuss were we want to go.

Early in my career I saw many examples where engineers were called on to design and build projects which had already been defined by non-engineers who completely misunderstood the problem. But the engineers usually made good scapegoats. So one lesson for me, in engineering practice, was that the most vital demand for sound judgment is required in the definition of the problem, and in the determination of the alternative solutions to be considered. Once the boundaries are set, the rest is mostly number crunching, with little or no opportunity to correct a major blunder. It is not enough for engineers to know how to do the thing right; we must also know what is the right thing to do. Otherwise, our education has failed us.

The essence of engineering is not design; it is the application of engineering judgment. I always shudder when a prominent engineer says, "I don't do engineering," or, "I'm no longer an engineer," simply because his or her responsibilities have grown beyond design. Analysis and design is the core of engineering. But, if engineering means only design--and if management of a technical program is not engineering--then obviously an engineer is not needed to manage it. Management schools and business schools zealously preach the gospel that a good manager can manage anything. And we play right into the hands of

those trying to replace engineer/managers with non-engineer managers. Engineer managers are troublesome because they might say, "No, it won't work," while non-engineer managers can be trusted not to know whether or not it will work.

For thirty years, in both industry and government, America has been replacing engineers with non-engineers in leadership positions. Is it any wonder that we have steadily eroded America's preeminent world position in technology? We know that America is losing billions in our foreign trade deficit partly as a result of tunnel vision decisions by our manufacturing industry. Isn't this a predictable outcome from the MBA Syndrome that places short term profits above all other considerations? We know that the rewards of technical ingenuity, as shown by awarded patents, are shifting steadily from the U.S. to overseas. Doesn't that raise questions about the way in which we are financing and rewarding our engineering research?

In less than twenty years the American space program has gone from a national pride to a national embarrassment. The realities of political and media pressures, versus technical and financial facts, are factors that affect not only the space program but almost all modern activities one way or another. But could you believe the nightmare ordeal of those engineers at NASA and Thiokol? In the life or death decisions involving a shuttle launch, did we really have a manager demand that the objecting engineer prove it <u>would fail</u>? The most horrible episode was the one where the manager tried to overcome the engineer's objections to the launch by telling him to "take off your engineer's hat and put on your manager's hat."

If that is the way America's leadership views engineering judgment, both now and in the future, our decline as a nation will not be gradual; it will be steep. To my mind the most fundamental challenge that faces us today is to reshape our system of engineering education to produce engineers who will soundly direct our technical programs and enterprises, and who will become part of national leadership, We must lay the foundation adequately for those unidentified engineering students who can reach leadership positions, and at the same time provide the corps of mid-level engineers who will staff our technical programs.

In 1970 I arranged for the speaker at the regional Engineers Week Banquet in Tidewater Virginia. We were privileged to hear an inspirational talk by Dan Pletta, University Professor Emeritus at Virginia Tech. His message described the 20th century development in America of educational programs for professional practice, and the contrasts between the paths adopted in law, medicine, and engineering. In his opinion engineering schools remained frozen in a 1900 pattern, while law and medicine had adapted to changing needs by exercising autonomy as separate "professional schools", <u>and</u> by adding progressively stronger prerequisites for admission. He urged that engineering also adopt the "professional school" approach, to enable the teaching of engineering practice to survive on a modern university campus.

As the grandson of a Virginia Tech engineer who also entered practice with a four-year B.S. degree in engineering, his message made sense to me. That was

the first time I learned of the national effort to form "professional schools" of engineering and I decided to support that movement. It was almost seventeen years ago... Now, you folks may think that you're looking at a 210-pound fat man, but that isn't really fat, that's scar tissue!!

Although I'm not a Westerner, I'm familiar with the term "fighting words". We are here this week to solve problems, not to recreate them, and I promise not to use the term "professional schools" again in this talk. But regardless of what we call the concept, we can't escape the bald truths that (1) the current four-year B.S. degree in engineering does not provide the educational foundation for American engineers to grow beyond technical specialists, and (2) without some degree of autonomy on campus, the current university undergraduate and graduate school system emphasizes knowledge and research to the total exclusion of teaching engineering practice.

So how does this point the way toward Educating Engineers for the 21st Century? First, let's really concentrate on defining the current problems. I believe there are several:

1. America is steadily losing its preeminence in technology. Other nations and cultures, where engineers are leaders as well as implementers, are gaining ground at our expense.
2. Almost none of todays engineering students are being educated for professional responsibilities. Without change almost all future engineers in the United States will reach a career ceiling as subordinate members of technical teams directed by non-engineers to implement programs defined by non-engineers.
3. The teaching of engineering practice on campus, by professors who have practiced engineering, is disappearing from our universities. The system of faculty appointments and promotions requires a Ph.D. and rewards success with research grant applications to the almost total exclusion of other values, such as teaching talents and experience in practice.
4. Engineering education in America is located predominantly in state-assisted engineering schools, and the financial foundations of these programs are woefully inadequate for the tasks. Unless the financial system or the level of support is changed, it will be impossible for engineering education to have the faculty and the facilities needed for the job. But throwing money at researchers to do research has not solved and will not solve the problems of teaching students.

Clearly these problems are interrelated. Our challenge is not simply to prune or reshape the individual trees, although this must be done. The primary task to to focus on the forest, and reshape the environment in which it grows. Let's change the system to make it move things in the desired direction. To educate engineers who will practice engineering in the 21st Century, our goal must be to groom preeminent practitioners who will be capable of engaging in participatory leadership

to formulate societal–technological missions. In a nutshell, we need to educate quality professionals. Anything less will be a disservice to this country.

But a new system of engineering education will fall short of its desirable and necessary objectives unless it incorporates not one but all of these features:

1. it must have access to the financial resources necessary to provide competitive compensation for a high level of experienced professional engineering educators, and to upgrade continuously the educational laboratories and facilities;
2. it must broaden the base undergraduate education in the professional program, to include more communications and liberal arts, as a foundation for a professional career;
3. it must include the teaching of engineering practice and ethics in the professional curriculum, develop an *esprit de corps* about being an engineer, and include a year of experience in industry under academic guidelines or control;
4. the overall system must continue to produce adequate numbers of graduates who are adequately educated for the many paraprofessional technical jobs in industry; and
5. it must include the built–in incentives and disincentives to persuade students, employers, and educational institutions to support the new programs.

Another lesson I have learned from practice is to avoid blaming people for serving their own best interests. I believe in progressive change, and I strongly believe in the ability of an individual to make a difference, but I don't believe in the reformation of human nature. If a system produces results, good or bad, it is very likely that the system includes rewards to human beings for contributing toward those results and/or penalties to human beings for failure to do so. You can trust human nature to be pretty consistent.

I'm reminded of the nine–dot puzzle. You know, the one where the instructions are to connect all nine dots with four continuous straight lines. Everyone tries to stay within the square formed by the dots, but the solution is impossible until you consider the use of lines extending outside the boundaries of the square. Nothing in the statement of the problem said to stay within the square. And we must not assume limitations that are not inherent in the statement of our problems in engineering education.

Some very fundamental boundaries involve the number of engineers needed and the definition of an engineer. Last summer the Deans provided some needed national leadership for our profession. They adopted a resolution which attempts to limit the use of the term "engineer" to individuals who possess either a state Professional Engineer's license or an ABET accredited engineering degree. The profession should be able to agree with that definition, whether or not we can convince the state legislatures. And, if we build the new system properly, almost

everyone who receives a professional degree will also seek and receive a professional license.

According the the U.S. Department of Labor, and to employers who are all too free to misuse the title, there are about 1.6 million so-called engineers in the United States today. But many do not have engineering degrees and less than twenty-five percent have a P.E. license. Clearly fifty percent of the total are no more than paraprofessionals. They don't even belong to one of our several hundred technical organizations. Both the individuals themselves and their employers see these "engineers" as technical jobholders, skillfully accomplishing a technical job under someone's direction. No one expects or desires them ever to hold any higher professional responsibilities. Their pay is commensurate with their performance and, except for some minor problems in communications, no one is dissatisfied with their current role in the system.

American industry needs several hundred thousand of these so-called engineers. In recent years this need has been filled by graduates with a B.S. engineering degree or a related science degree. A more well-rounded engineer would be wasted and bored in these positions if he or she spent more than three to five years there. Industry will not pay more for an engineer who is better educated than the position requires.

Perhaps it is a mistake to label these people engineers. Their primary motivation is not the title; it is the paycheck. Most of these people were first generation college students pursuing higher pay but not professional status or responsibilities. They are equally attracted to engineering or engineering technology if the sales pitch on benefits is the same.

Where is it written that we must choose between "<u>all</u> engineering graduates" being prepared for professional responsibilities or "<u>no</u> engineering graduates"? If we upgrade the requirements for engineering education to meet the needs of practicing professional engineers in the 21st Century, can we not recognize that only half as many of these graduates are needed? At the same time we could also upgrade the requirements of engineering technology programs to meet the needs for skilled technical employees who are not broad-based professionals?

In 1985 our colleges and universities awarded about 78,000 Bachelor degrees in Engineering, and about 26,000 Associate and Bachelor degrees in Engineering Technology. The National Research Council has a Committee on Education and Utilization of the Engineer. In its 1985 report it found that "there are many engineers who do technical-level work". However, the Committee felt that "there is no need to redress the technician/technologist/engineer balance" because "the system seems to find the most appropriate balance via market mechanisms". In other words, America shouldn't worry about the distribution in the educational system so long as enough total bodies are produced. The market will redistribute them as needed. I believe that conclusion is fundamentally wrong, and it lies at the root of our dilemma.

We have been struggling for decades to address the limited need for a strong core of engineering professionals for America. But we continue to accept the size of the current output from engineering schools which produce both professionals and paraprofessionals. In those terms, like the nine-dot puzzle, the problem cannot be solved.

But, if we choose to separate the problem, and to upgrade only the core group, we will need to distinguish clearly between the two products. There are two ways to do this: We can abandon the term "engineer" to the technologists and adopt a new term, such as the European *ingenieur* with an "i", to describe the professional program. Or we can follow the advice of the Deans and hold to the ABET entry-level engineering degree as the appropriate base credential for the term "engineer". In the latter course we must recognize that the standards will be rising while the numbers entering a more selective American engineering profession will be shrinking.

The American engineering profession has access to only two institutional tools with which to encourage these improvements: accreditation of professional degrees and professional licensure. Neither tool is easily changed but both can be changed if we provide the justification, and if we provide the energy to accomplish it. Perhaps we need a Congress on Engineering Licensure to follow up on this Congress on Engineering Education. If the National Council of Engineering Examiners and ABET could agree on a coordinated program, the possibilities would be unlimited. With the incentives available to ABET and NCEE, human nature could be working in our favor.

As an incentive for a longer and improved entry-level professional degree program, why not provide immediate access to the state professional license? If a one-year directed internship is built in to the professional degree, through the co-op program or otherwise, why not waive the current four-year waiting period for the P.E. exam? The profession might not lose so many from professional licensure if it were available on graduation to engineers as it is to doctors, lawyers and other professionals.

Many students would continue to enter the work force with only a four-year technical degree, adequately prepared for a technical job but poorly prepared for a professional career. To clarify this distinction their degrees must be denied accreditation as degrees in engineering. Accreditation might still be available in engineering technology or engineering science. ABET should also require that all programs with engineering titles at a university be submitted for accreditation, or none will be accredited.

No Bachelor's degrees would be accredited in engineering. The longer professional program would be accredited at the Masters level. If today's B.S. engineering graduates need about 4.7 years, without adequate preparation in communications and liberal arts, at least six years will be required for a practitioner in the 21st Century. But on campus the earliest years do not have to be in the engineering school if it can raise the standards for admission. To describe those

complete programs which include a least twelve months of directed off–campus internship, we could revive the little used professional degrees of "Civil Engineer", "Electrical Engineer", "Mechanical Engineer", etc.

Key to the success of such a program would be the close ongoing cooperation between engineering employers and academia on which to build the internship or co–op arrangement. It would have to be stable––at least a ten year contract––and mutually beneficial. ABET would be a proper clearinghouse or broker for industry/university arrangements. Possibly the compensation provided by the employer could be shared between the student and the university. As with the current co–op programs the employer gains a "first crack" at a continuous crop of new engineers educated for practice. If the internship is properly monitored on campus it will build a faculty/industry relationship, similar to a teaching hospital. That relationship offers the potential for many mutually rewarding exchanges, including visiting professors from industry and consulting assignments for faculty.

The employer cooperation is vital for another reason, the marketability of the product. Unless industry, and other employers of engineers, accept the products of a professional degree program as more valuable than the current four–year B.S. graduate, the starting salaries will not be higher and this program will fall on its face. Apparently, this was the experience twenty years ago when several progressive engineering schools tested the water with a five–year program. If, through industrial participation in the internship element, we can demonstrate the ability of professional degree graduates to "fast track" past limited technical jobs to broader responsibilities, the market will promote this program instead of killing it. But major employers must be involved if they are to be convinced.

Finally, there is the university. Academia is supposed to include the best brains involved in the system, but it is also the most resistant to change. We must break free the position of engineering faculty within the university structure so that professors of engineering practice can be and will be compensated at the level they deserve.

One possible change might be to disengage graduate engineering education from undergraduate engineering education. Our present system seems to reward involvement in research and in the graduate level program at the expense of the undergraduate. It seems oriented to preparing undergraduates for graduate school and research rather than preparing them for engineering practice. If the undergraduate program is separated, with its own Dean and its own budget, it could evolve into the needed professional practice orientation. The graduate program with its research activities could stand on its own merits.

Another change, directly aimed at the income of professors of engineering practice, would be the creation of an associated non–profit corporation attached to the engineering school. This could serve as an agent for the engineering faculty to use in practice, consulting and research activities. It could supplement the basic university salaries in a pattern now used by some medical and law schools. I can sense the grumbling from some consulting engineers fearful of competition from

professors, but we can't have it both ways. If the teaching of engineering practice demands up-to-the-minute competence in engineering practice plus teaching abilities, then clearly these professors deserve compensation above the engineering averages.

Only those universities that are willing to change their system will be able to provide superior support for a professional engineering degree program to meet 21st Century needs. Only those universities willing to provide the needed superior support will deserve to have one. Many existing schools will not meet these standards, and they can continue to offer a pre-engineering program or possible accredited engineering technology or engineering science degrees. But that's okay, because these graduates can also be placed in productive jobs. But let's not pretend that they are professionals and let's not call them engineers.

In summary, let me attempt to describe the shape of engineering education in the 21st Century.

I see a system of engineering schools, maybe half of those we have now, producing forty- or fifty thousand graduates each year with professional degrees. These degrees require six or seven years of higher education, including a solid foundation in the arts and sciences, and a twelve-month internship. Their engineering professors are all experienced in engineering practice, all licensed professional engineers, and include many of the most respected engineers in America, who are models for their students. The new engineers are true professionals admitted to the P.E. exam on graduation, and much sought after for fast track positions in technical programs for government and industry. They have a sense of worth as engineers, taught by their professors, and they expect to see fellow engineers among the natural leadership.

I also see a system of higher education providing competent paraprofessionals to support our technical programs. The nation may need as many as 200,000 per year to stay competitive internationally. These people may obtain four-year Bachelor's degrees in engineering technology, engineering science, or applied sciences, but they are not engineers any more than dental hygienists are dentists. They can become engineers through professional licensure, like anyone else. But without a professional degree, the experience requirements will be lengthy and stringent and must be under the direction of a professional engineer. An alternative path for the brightest of these Bachelor's graduates would be to pursue graduate degrees--M.S. and Ph.D. in Engineering Science--and to staff research laboratories. A professional license is not relevant to a research career.

Bobby Kennedy said, "I see things the way they might be, and say, 'Why not?'" Well I'm not in the habit of quoting Bobby Kennedy, but if we believe America needs these changes in engineering education...why not??

The engineers attending this Congress are here with a common cause: to improve engineering education. By definition, engineers are ingenious and we are problem solvers. I have said earlier that the essence of engineering is not design, it

is the application of engineering judgment. I hope that my thoughts have stimulated your creative thinking.

Let us resolve that, before we leave tomorrow, we will bring our best judgment to bear on how to solve the problems we face. And let us not be timid and dare too little. It really is not stretching to suggest that the future of America in the 1990s as well as the 21st Century depends on its engineers.

In the sixties a hit song by the Byrds borrowed its refrain from Ecclesiastes:

"To everything (turn, turn, turn,)
There is a season (turn, turn, turn)
And a time to every purpose under heaven..."

Ladies and gentlemen, this <u>is</u> the season and this <u>is</u> the time for significant changes in Engineering Education. Let us make the most of it!

Dr. Roland W. Schmitt
Senior Vice-President and Chief Scientist
General Electric Co.

National Congress on Engineering Education (NC2E)
Accreditation Board for Engineering and Technology
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THE CREATIVE MIND AND THE COMPETITIVE CHALLENGE

You may have heard the story about the Frenchman, the engineering educator, and the engineer who were sentenced to the firing squad. They were each asked if they had a last request. You can imagine what the Frenchman asked for. The engineering educator's last request was to be permitted to read his study on the state of engineering education in the United States today. At this point, the engineer interrupted with his last request-- "shoot me first --so I won't have to listen to another study on the state of engineering education in the United States today."

I sympathize with him. We have heard an awful lot of studies on that topic lately--the NRC's study on Engineering Education and Practice in the United States--the Haddad report--the NSB's study on Undergraduate Science, Mathematics and Engineering Education, the QEEP Report, and more.

I'm not going to add to that list. Instead, I'm going to build on a statement made by one of my favorite educators--Yogi Berra. He once said of baseball, "50% of the game is 90% mental." Well in regard to those studies of engineering education, I would say that 50% of the questions they ask are 90% on target. They have concentrated on questions of quality, effectiveness and excellence of engineering and engineering education--all questions of supreme importance.

But, I believe they are only 50% of the right questions because every other question should be the same one, repeated over and over and over again. The question needs to be repeated, and repeated often, so that we won't for a minute lose sight of why we are asking all of the other questions today. That question, in simple, raw terms, is "Why do the Japanese beat us so often?".

I use that question as a dramatic and vivid surrogate for the whole issue of international industrial competitiveness and not to stand before you in a fruitless exercise of Japan-bashing. But, the simple fact is that Japan, above all others, has defined the international competitive arena--so they are a good surrogate for the broader problem.

In the race for competitive advantage in technically-based commercial markets, the U.S. and Japan go about the race in very different ways. America usually gets off to a leaping start--for example, inventing the transistor, gene splicing, the

integrated circuit, and the videotape recorder. But then it snoozes or stumbles. The Japanese typically are not so fast out of the starting gate--but they don't have to be because they don't start from the same starting line. Instead they stand a bit down the track, see how the race begins and then jump in with a rapid, well organized, and, very effective engineering effort that combines rapidly executed incremental technology steps with superb design, manufacturing, and quality control. And they are preeminently successful in linking their research to markets. As a result, they gain competitive advantages in industry after industry. That contrasts strongly with the American strategy of combining technology leaps with stumbling efforts to translate that technology into commercial success.

The Japanese have recognized the differences I have just described. You may have read about their new government-funded Exploratory Research for Advanced Technology program, and other initiatives, aimed at improving their ability to make creative breakthroughs. So in the area where we are strong, our strategies are converging. But they are not converging rapidly enough in the area where <u>they</u> are strong--executing innovations with speed and efficiency.

I suggest that the challenge of competitiveness has two parts--maintaining and strengthening our ability to make great leaps of creativity, in which we continue to lead the world...<u>and</u> executing innovation with speed, efficiency, and attention to the issues of quality and manufacturability, where we have slipped.

Tonight, I want to look at both parts of the problem, starting with that ability to leap ahead and make creative contributions. That ability, where the U.S. has excelled, is under pressure today, and those reports I've cited a moment ago do an admirable job of describing that pressure in the universities. University science and engineering departments lack adequate equipment. National Science Foundation surveys show that one-quarter of academic research equipment is obsolete, one-third is more than ten years old, while less than one-sixth can be called state-of-the-art. University buildings and fixed equipment are in a sad state. Some estimates suggest that $5 to $20 billion will be needed just to meet the facilities need. Faculty vacancies are running over 8%, compared to the usual 3%--and this challenge will become extraordinarily crucial in the 1990s when the generation trained in the postwar "golden age" of U.S. science and engineering reaches retirement age. And, finally it's an incredible fact that Japan, a nation with only half our population, now graduates more engineers each year than we do. The demographic charts indicate that the problem will get worse, not better--the number of 18 year olds will fall by 25% in the next decade and the structure of the college population will shift toward groups, such as women and minorities that have traditionally been less prone to choose science and engineering. And all of these changes will be occurring in the context of increasing demands, and tightening budgets.

Given those pressures, can the creative engineering mind thrive and be as productive as it has been in the past?

My answer here is yes--if we do the job right. The environment of the researcher can be enriched if these challenges are regarded as just that--challenges, not threats. And the environment can be enriched if we use the challenge of competitiveness as the rationale for the funding needed to relieve the pressures.

This approach can work because creative people are harder-shelled creatures than many of us give them credit for. They thrive on putting together diverse information in creative ways. Some of the greatest research discoveries result when a creative mind uses the findings of one field to enrich the methods and concepts of another. Consider the way Carnot brought the steam engine into physics, or the use Darwin made of ideas from economics, for example. The realities of today's competitive world can become part of this rich stew of raw material for the creative process. Competitive challenges can pose new kinds of questions for the researcher, can trigger new kinds of approaches. They can lead to discoveries, ideas and new knowledge every bit as creative as in the past, yet more responsive to the new imperatives.

Both industry and university leaders have responsibilities for broadening the flow of challenging problems and innovative ideas moving between the universities and industry from today's trickle to a much more substantial flow. The Nobel Laureate and President of the Royal Society, Sir George Porter, summed this up very well recently when he said, "The link up between basic research in the universities and industrial needs must be initiated to a greater extent by those in industry. They may expect the full cooperation of the university research worker--the days of ivory-tower snobbishness about pure research are long since past."

Let me be a little more specific about this link up by looking at one area where it is especially crucial--the area of engineering research. It generates much of the knowledge underlying the practice of engineering, and it provides a crucial bridge between the leap-ahead ideas in which this nation excels, and the ability to use those ideas. A few years ago, many of us became concerned that the nation was falling down in engineering research. The Committee of Science and Public Policy of the National Research Council, for example, found universities reluctant to grapple with the research issues underlying advanced automation, in such fields as human computer interfaces, expert systems, and geometric modeling. It found universities weak in crucial fields of materials engineering, such as advanced polymers, composites and ceramics. And in biotechnology it found that we are not developing "a knowledge base in process engineering that combines the skills of the biologist and the chemical engineer."

Once the needs were identified, an initiative was launched to meet it. The National Science Foundation created a program of Engineering Research Centers located at universities and aimed at enriching engineering research. The centers were explicitly designed to link industry and universities--creating bridges that would carry not merely money, but, much more importantly, the challenging problems and stimulating people who can enrich work at both ends of the bridge. They were designed to be truly interdisciplinary. And they were designed to take a

broad view and embed engineering research in the total process of innovation needed to make our nation more competitive.

As many of you know, the response to the program has been overwhelmingly positive. The initial offering was only $10 million for the establishment of three to six centers. That drew some 140 proposals requesting a total of more that $2 billion. That strong response helped confirm the need for the program, and it is now launched and growing in a second round, with a total of eleven centers established so far. Industry is now providing about half the support for them.

Those Centers are just one example of enriching the environment of researchers by immersing them in the competitive challenges created by the new world economy. We need similar initiatives across the board, in science as well as engineering. They will not direct science away from excellence.

And one such initiative that universities themselves must address is establishing more interdisciplinary professorships. A few universities have crossed this line in a few areas, such as materials. But as the world of technology advances and changes, universities cannot be laggard in their responses to it. While preserving the values of traditional disciplines, universities must also move strongly to the realities of a changing world.

My confidence that such initiatives will enrich research itself is heightened by the track record of the past. Time and time again, such challenges have produced not only practical answers, but also better research. Consider, for example, the chemistry of Lavoisier that enriched his projects in the field of agriculture...the bacteriology of Pasteur, inspired in part by consulting work for the wine and beer industries...the discoveries in physical chemistry of Haber and Nernst, stimulated by the need for nitrogen fertilizers...the surface chemistry discoveries of Langmuir that began with studies of the blackening of light bulbs...Jansskey's pioneering work in radio astronomy, stimulated by his studies of static...the discoveries in such areas of physics as elementary particles, and nuclear magnetic resonance that grew directly out of radar work during World War II...or the more recent work carried out both in industry and academia in such forefront fields as artificial intelligence and new computer architectures...and right up to this year's Nobel Prize winning work, done in an industrial laboratory, on scanning tunneling microscopy, an exciting new way to see atomic lattices on surfaces.

That long track record gives me confidence that the environment of the researcher can be enriched by these new challenges.

But that is only half the problem--and probably the easier half. We are still faced with that other issue of effective execution--of strong performance all the way to the finish line. Here research is <u>not</u> the answer. Although we do need more engineering researchers, as I just suggested, the rest of our engineers--the vast majority--need to be trained less like researchers than they are today---and more like old-fashioned, practicing, dirt-under-the-fingernails engineers.

Although I have not personally spent my career on this half of the problems, I have been close enough to it to ask a few questions that I do not see being asked--though I have to say, again, that the QEEP report does ask many of them.

First question--are most American engineers trained to face the exacting process of concentrating on the many steps between the impressive opening leap and the finish line of commercial success? Do they follow through on the engineering details as rapidly or effectively as they should?

The answer is that they do not. Instead, we often treat everything as a research problem--a problem of creating the elegant, inventive solutions without adequate consideration of cost, manufacturability and quality. We tend to exercise our ingenuity at building new features into products, while the Japanese exercise their skill on those features that are really needed, features with customer value, and keep strictly to stringent targets for cost and quality.

There are at least two explanations for our behavior. Perhaps the engineers are being mis-managed. That is an issue which I have addressed before industrial audiences--the ones who need to hear that part of the story. But today I'll concentrate on the other part of the answer--the possibility that engineers are not being educated to meet the competitive challenge.

This is a cultural problem. Throughout this century, we have seen a growing emphasis on fundamentals and theory, at the expense of hands-on experience. The objectives of this change were laudable--to give the engineering graduate a command of the fundamentals, rather than a mere exposure to obsolete machines and superficial shop techniques. Which leads me to my next question--has the process been carried too far? Has the rise of theory-based engineering education separated the student from the real-world? Are students who will work in a competitive culture being trained in a culture of research and analysis--the culture of their professors? Are the values imparted by our education system, research and academic values, emphasizing the optimum solution, and putting little emphasis on such problems as speed, cost, and customer satisfaction--the values of the marketplace?

Lest you think this problem is new and thus not a factor in losing so many competitive battles with Japan, let me tell you a personal anecdote about myself and one of your allied societies, ASEE. In late 1965, over 20 years ago, I gave a talk at one of their meetings. The spirit of that talk is captured in a brief abstract from it, where I said, "The engineer, to fulfill his true function, cannot be guided solely by the technical interest of his work with no regard for its potential usefulness; he cannot indulge in the scientific sport that wants for nothing but an idea and its support!...Today, perhaps, the pendulum has swung too far and we should, without ceasing to be scientific, become practical again."

Two things happened. A faculty member in the audience attacked me as not qualified to make such judgements and the paper, based on the talk, was rejected

by the Journal of Engineering Education as being "limited in approach and hence unsuitable for publication." I suggest that some of our problems with Japan today can be traced directly back to our views about engineering education then!

Those academic values have perhaps been reinforced by that portion of the U.S. industry dedicated to aerospace work, where performance and features have been the key. But, they can be disastrous in commercial work and, today, even aerospace is changing. These academic values have crept into U.S. industry in a way that does not happen in Japan.

Again, I have to fall back on anecdotal evidence. Consider for example, the area of automation, where the Japanese company Fanuc has made an incredible rise to world leadership in recent years. One of my General Electric colleagues recently discussed this issue of engineering execution with some of his counterparts at Fanuc and got an interesting perspective. The difference between U.S. and Japanese approaches, he was told, is the difference between a snake and a wall. Both U.S. and Japanese companies start a project aiming at roughly the same cost and performance targets. But the U.S. engineers, in their obsession with performance, allow the characteristics of the product to snake upward in both performance and cost, until they have purchased performance improvements at a cost the customer is unwilling to pay.

The Japanese company, by contrast, begins the project by erecting a wall. It might be a cost wall, as it typically is with Fanuc's automation products. It might be a size wall, like the one established by the manager at Sony who brought a wooden block in to his engineers and told them--you must design our compact disk player to stay within the size of this block. The wall is rigidly enforced, and the engineer is challenged to build the best product he can without crossing the wall. The result often cannot match the peak performance or features of the American rival. But usually it surpasses the American product in the total package of performance, quality, and cost.

That snake-versus-wall comparison is not the whole story. There are also issues in the speed of innovation, the size of the innovation steps one tries to implement all at once, the need for patience and persistence, and many more. All these points do not add up to some inscrutable oriental cultural advantage. They are just good old fashioned engineering. They are best expressed not in sayings of Japanese sages, but rather by that anonymous Western engineer who, many years ago, defined engineering as "the ability to do for one dollar what any damn fool can do for two."

Has our nation departed from the course this maxim marks out? What can we do about it? In saying, earlier, that our engineers need to be trained less like researchers than they are today...and more like old fashioned, practicing, dirt-under-the-fingernails engineers, I didn't mean to return to slide rules and drafting tables. The modern practitioner must be trained to use modern tools for practical ends. Computer aided engineering can speed up the execution of engineering projects. Eliminating paper from the manufacturing process, and enabling

the engineer to test ideas quickly and inexpensively on computer simulations can drastically cut down the length and cost of the design cycle, and lead to better quality products in the bargain.

Another technology, artificial intelligence, might help with the cultural problem If old-fashioned engineers are really an endangered species, perhaps the answer is to clone them electronically. Using expert systems, it's becoming possible to capture the knowledge and skills of an expert designer, trouble shooter, or manufacturing engineer in a computer program. That can be a tremendous tool to assist or educate the young engineer.

But we shouldn't look to technology for the whole answer. I ask you whether or not something more is needed than the additional money, additional equipment, increased use of computers, and the other reforms the various reports call for. Again, I think the QEEP report is on the right track, especially with its recommendation that "Engineering schools of all types should seek to employ as many faculty as possible with industrial experience."

I was interested also to see its recommendation that the engineering profession join the state of California in making English its official language. I was a bit disappointed to see that recommendation restricted to foreign born engineers, however. I've met plenty of American-born engineers--and corporate executives as well--who should be required to pass the Test of Spoken English the report refers to!

More seriously, reforms are needed, perhaps even some experiments with extensive redesign of engineering education. Perhaps we need to put the pieces together differently, and also add some totally new pieces, to fit a new world.

Some of the old pieces might turn out to be more relevant than ever. For example, co-op programs can give a student a better advance taste for the type of life he will encounter after his degree. I'm aware of the problems of co-op education--inconsistent support from industry, high program management costs, and faculty program design--but I agree with the authors of the Haddad Committee's findings that these problems can be fixed.

And there are other proposals. For example, Bernard Friedland of Singer, and Peter Dorato of the University of New Mexico, have suggested that engineers be trained like doctors and lawyers, and not enter into specialized study until their postgraduate courses. Only then will they have the capability and the incentive to really apply themselves to specialization. This proposal deserves a close look, and, perhaps, an experimental trial.

A second suggestion as been put forward by Nam Suh of the NSF. He points out that teaching the fundamentals is not sufficient--you also have to choose the <u>right</u> fundamentals. In engineering, the choice of fundamentals has been one sided. The emphasis has been on analysis--taking things apart--rather than

synthesis--putting things together. Engineering has been taught as though it was merely applied science aimed at analyzing a man-made universe.

But there are also fundamentals unique to engineering synthesis--fundamentals underlying the processes of design and manufacturing. Part of the reason they are not taught is that they are not understood very well--either in academia or in industry.

It may turn out that the only way to become a good engineering designer is by experience--that is, by creating a lot of bad designs, and learning something from each one! But I would hope not. Again, Nam Suh has a good suggestion here, of providing engineers with the equivalent of a medical school's teaching hospital. I should point out though that the analogy is not perfect--unlike doctors, engineers can't bury their mistakes!

As a final guideline I believe we need to keep working on industry-university interaction. For example, the president of one well known university, losing patience with the clamor for increased industry financial support of universities, remarked, "Don't just send money...send the best people who have thought deeply about the process...and not just for a day or a week, but full time for months." Right now people on both sides of the fence give lip service to industry university interaction. We can point to a substantial number of industry people who move on to teaching careers. But a closer look shows that the industrial people who go to academia are often the ones already most like professors in their outlook and activities. The masters of engineering execution in industry rarely have the time and inclination to spend much time on campus. But we should find ways to make it worth their while, and worth the while of the company that pays their salary. And, in the same way, I have considerable sympathy with the proposal that a few years working on the factory floor on manufacturing and design problems in industry ought to count at least as favorably at an assistant professor of engineering's tenure hearing as theoretical or analytical papers in a professional journal.

The objective is not to reduce the emphasis on learning the fundamentals of engineering but, rather, to ensure that the engineer knows how to use those fundamentals and is motivated to satisfy his customers and clients, not just himself and his technical colleagues.

Well, I've presented some questions and opinions that represent my personal reaction to the problems of engineering education. To sum up, the link between the creative mind and the competitive challenge has two parts--maintaining and strengthening our ability to make great leaps of creativity, in which we still lead the world...and executing innovation with speed and efficiency, where we have slipped. We are doing very well at addressing the first of these parts, but we need to do much more on the second.

In speaking of this issue, I leave you not with an answer but a challenge. it is a challenge that cannot be ignored. The new world economy, based on knowledge,

training, and skill, is here. The implications of international competition will permeate all of U.S. science and technology.

Fortunately, the challenge of competitiveness does not require a sacrifice of the creative mind. Just the opposite. Once again, as so often in the past, I am confident that responsive science and technology will be creative science and technology. Presenting new challenges to researchers and educators will not weigh them down. It will spur them on to new achievements in both broadening knowledge and serving society.

CURRICULUM ISSUES:
A Summary and Overview

Gene M. Nordby
President, Accreditation Board for
Engineering and Technology

Presented at the
National Congress on Engineering Education
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It is common knowledge that there has been a deterioration of the Nation's economy in the past decade. The effects of world competition and the global economy came upon the United States rather quickly as other countries found their niches in the marketplace. Perhaps this was due to our domination of the world markets for almost 200 years and a certain arrogance we developed as a result. Our trade deficit in 1986 will approach a record $200 billion. Now the Nation is aware of this multifaceted problem, and remedial action is beginning in many sectors to regain and, hopefully, maintain our leadership in the world markets. The engineering profession is the foundation group upon which the nation is dependent for innovation, product design, and technical service to restore quality, economy and superior performance to our manufacturing processes, production of goods for our own consumption, and for a strong position in world trade. As a result of industry trying to improve its competitive edge, it is making new and different demands on engineering education. Thus, it is critical to hone our engineering education to meet these needs for competing at higher levels than ever before.

The National Science Board's recently issued report on *Undergraduate Science, Mathematics and Engineering Education* begins with the sentence, "Serious problems, especially problems of quality, have developed during the past decade in the infrastructure of college–level education in the United States in mathematics, engineering, and the sciences." The report continues, "The only way that we can continue to stay ahead of other countries is to keep new ideas flowing through research; to have the best technically trained, most inventive, and adaptable work force of any nation; and to have a citizenry able to make intelligent judgments about technically–biased issues." This is the reason for the National Science Foundation increasing its focus "...on the essential bridge between the schools and the national apparatus for research and development; [and] that bridge is undergraduate education..." It is essential that we support their efforts in this regard and support their initiatives to help in our undergraduate efforts. One of the broad resolutions of this congress is aimed at this effort.

The NSF's conclusions are reinforced by the Accreditation Board for Engineering and Technology's reported accreditation results over the past several years. In the 1985–86 accreditation cycle, only 28 percent of the programs examined by ABET achieved the maximum accreditation period. This has dropped

from its traditional level of 55 percent prior to 1980. At the same time the "not-to-accredit" and probationary actions doubled to 21 percent. There are deficiencies in laboratory instruction, design and innovation instruction, and a general lack of attentiveness to undergraduate instruction.

Engineering education has not changed its basic format since the late 1950's when the famed Grinter Report was published, putting more emphasis on science and research in engineering. Many think our engineering graduates are the best that our universities have ever produced, at least in their technical training. Nevertheless, considerable dissatisfaction is expressed by industry spokesmen about the lack of certain attributes of the newly-graduated engineer. The time has come to take another step forward, building on our past experience. The dominant suggestions of industry, merged with the main suggestions of the multitude of reports the committees studied in preparing for the Congress, are now summarized.

The newly graduated engineer's needs are:

a. more liberal arts and humanities, some knowledge of a second language to better understand other cultures and to work with people internationally, and a better preparation for the legal, social and ethical problems they will face in industry,

b. more cross-disciplinary technical study with greater breadth in the engineering sciences,

c. more depth in the discipline of choice,

d. more ability in the design and innovative process, particularly in computer-based engineering analysis and design,

e. more exposure to business practices that involve the engineer, to be able to evaluate economic factors and the role of finance, and to be able to think of product lines in global terms,

f. exposing the engineering student to industrial life in an interning mode, and

g. conserving the diversity we now enjoy in engineering education, and seeking to add to it as the needs develop.

Obviously, proficiency in all of these areas in a four-year program is not possible and probably is not possible in a five-year program, while still maintaining a high level of technical proficiency. Since the current four-year engineering programs take 4.5 to 4.7 years, on the average, to complete, redesign of the curriculum should be considered. With the knowledge that the power of the American education system lays partially in its diversity, different engineering programs emphasizing different aspects of the areas mentioned should be tried in a search for the optimum.

However, it must be stated up–front that engineering schools are good at providing the basic foundation for a career in engineering, but they cannot provide a polished engineering inoculated with enough information to last through a lifetime productive career. Industry is better at providing part of the education. It should insist that its engineers keep up–to–date, and it should aid them in career development through continuing education programs of either a formal or informal nature. Still, this is an area that the National Research Council's report states is a "...haphazard process of on–the–job learning, company training programs, seminars, conferences and professional reading." Broad Issues Resolution No. 10 deals with this question and recommends that ABET continue its current experimental efforts in assessing the quality of continuing education and cooperating with anyone who asks for such aid. In particular, ABET should be invitational in aiding and accrediting successful continuing education programs for the professional, such as those offered by the National Technological University.

There are several ways schools can deal with the curriculum content demands previously outlined. First, the schools must decide what they are best at doing and defer to industry those things which the schools cannot do. Second, the schools must look for efficiency in the current programs and eliminate redundant coverage of that coverage less important for the current need. emphasis should be placed on the most currently important areas. Third, they should consider extending the programs so that they will be truly professional curricula.

As an alternative to these three steps, the schools can do nothing. This option will have a significant following among our constituencies and at this Congress. Inertia is difficult to overcome. There will be many excuses: ABET has no right to tell the universities what to do! The university will not approve or cannot afford these changes. Our faculty cannot teach those subjects, etc. I have heard all the excuses already, each based mostly on local conditions. I urge you to think of the profession and the requirement of producing the very best engineering graduate we can in order to meet our country's future needs. That is why ABET organized this Congress; they can set criteria and, over a period of time, make changes. It is the only mechanism we have! Furthermore, since everyone participates in ABET, all the constituencies can take part, and directions can be established. That is exactly what happened in implementing the Grinter Report in the 1950's. ABET can neither dictate nor set irrelevant criteria because, in the end, nothing will get done anyhow.

Let's look at the curriculum efficiency items first. Curriculum Issues Resolutions Nos. 3 and 4 suggest that the standard and traditional physics/chemistry and mathematics course sequences be brought up to date. This would be accomplished by casting out those parts which are the least useful and that are overlapping with other parts of the engineering sciences, and introducing information of a more modern and useful character. This would involve some experimentation. The proposed NSF support program may be able to aid in studies of alternate programs, perhaps in conjunction with mathematics and science societies.

ABET has made special efforts to improve treatment of the areas of communication skills, computer skills, and the design process. Curriculum Issues Resolutions Nos. 1, 2, 5, 6, 8, and 9 deal with various parts of these issues and their reinforcement. Some of the changes are attitudinal in nature where course structure changes and teaching methods would aid in solving the problems. Some general comments follow.

Over the past decade we have often squeezed most of the traditional report writing from our laboratory classes. Grading is often done by graduate assistants whose command of the English language is weak, too. Further, there is no reason why we cannot have writing assignments in every engineering course with part of the course grade dependent upon the exhibited writing ability. We must make the student feel that writing is important to engineering and consistently pursue its improvement.

Design teaching also has become weak. It is perhaps human nature for the faculty member to concentrate on analysis. The problems have precise solutions and are easy to grade. But innovation, creativity and the systems approach to engineering design is the essence of what we hope is the outcome for the student from the engineering programs. In attaining this end we should emphasize such subjects of importance, such as the manufacturing and construction process, robotics, microprocessing, and quality control. These programs should continue to include considerations of economic factors, safety, reliability, aesthetics, ethics, and social impact.

Another issue, almost as consistently mentioned as the communications deficiency, is the lack of interdisciplinary knowledge. Since the Grinter Report, which emphasized the engineering sciences, we have consistently narrowed our focus on these subjects, covering only those which most directly apply to individual programs, such as electrical engineering, mechanical engineering, etc. We need to broaden our scope again. The ABET Participating Bodies will have to give up some of their perceived need for as much professional coverage at the four-year level and encourage this coverage in the fifth year. We also need to increase the ability of engineers to recognize how their individual work is affected by adjacent fields. Curriculum Issues Resolution No. 7 deals with this issue.

General education and/or a liberal education seems to be a hot topic on most campuses. There is the threat that more time will be taken from our four-year program for university-wide programs in this area. Most of the thrust comes from the dictates of the liberal arts faculty, particularly those in the humanities. In engineering, we believe that a liberal education consists of an education in five areas: social sciences, humanities, mathematics, science and technology. Along with pharmacy, engineering may be the only undergraduate program that incorporates all five. The proportions we assign to each may be incorrect, but we make some attempt to include all within the time constraint of four years. However, it must be noted that the humanities/social science portion of the ABET requirement is the most carelessly administered of all the areas. No wonder others in the university think we need more education in this area. We do not seem to be serious about

our own requirements. Still, some recommendations from the liberal arts faculty appear to be more aimed at their own interests in the university structure than for a liberal education--we all have our biases. We must use care in negotiating with them, and we must decide for ourselves how to formulate the best engineering program. Nevertheless, we must improve our knowledge of other cultures, global economics, ethical issues and other subjects, not only to be better engineers, but to be better and more participatory citizens. Curriculum Issues Resolution No. 10 deals with this issue.

It appears that no matter how much efficiency we bring to the four-year program, there is not enough time to do the things the university can do best for a truly professional engineering program. Although a five-year program may not be long enough to teach everything needed, it would be a start.

In order to accomplish the changes, we need a transitional period so that institutions can make orderly curriculum experiments, so that we can assess the results, and so that no school will be economically injured or be pioneering its way towards a disaster. No individual institution should take a chance on a five-year program standing alone. After the experiences of the University of Minnesota, Cornell University, Ohio State and others in the 1950's, even if a school was committed in its soul to the necessity of the longer program, it would not dare flirt with the inevitable financial disaster.

With this general set of conditions in mind, the resolutions are formulated with a plan towards evolution rather than revolution. Thus, ABET must encourage institutions to experiment with different carefully designed formats of engineering education, with the accreditation process placing as much emphasis on outcomes as possible, with less prescription of particular courses, and without jeopardizing the essential information that every engineer must learn.

Curriculum Issues Resolution No 13, and I hope it is not the unlucky 13, is key to this process. It encourages the following actions:

1. Continuing a four-year engineering program by specialty, but more general than current programs, possibly with more liberal arts and engineering sciences, together with revised sequences in mathematics and science for more efficiency, but with less specialization.

2. Development of integrated five-year programs which will provide considerable specialization in the fifth year beyond the four-year program. This is intended to be the future entry-level professional engineering degree.

3. During a transition period, "four plus one" or "three plus two" year programs would be consistent with this progress. In fact, as institutions focus on their goals and capability, these may become standard approaches.

4. Re-institute dual-level accreditation by ABET so that both advanced (graduate) level and basic level programs may be granted accreditation at the same institution. Currently, the institution must make a choice between the two. This effectively bars progress towards a longer program in a transitional period.

5. Notifying the National Council of Engineering Examiners that at some future time, say 1995, ABET will accredit only the five-year program as the minimum program that qualifies the recipient for entry into engineering at the professional level and, in our opinion, qualifies the recipient for the registration process.

This covers all the issues in a general way. Each participant should read each of the resolutions carefully, keeping in mind the main thrust of the resolution. Let's not quibble about wording and hidden intents; the resolutions are intended to convey main ideas which can be refined over time as we learn more of the effect of each.

SUMMARY:
National Congress on Engineering Education

Leighton E. Sissom, Ph.D., P.E.
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Chairman, Engineering Deans Council of ASEE

I understand that the NC2E Executive Committee had to search long and hard before they found someone gullible enough to accept the job of summing up this Congress. When I look at the history of the people from Tennessee, I can appreciate that. We are sometimes slow to catch on. A few years ago when the automotive manufacturers changed the headlight dimmer switch from the floorboard to the steering column, we had 19 Tennesseans break their legs getting them tangled up with the steering wheel. I was so slow to figure out that this role of summarizing the Congress is a mammoth job that it was upon me before I could back out.

In the test question which a randomly-selected sample of this body voted on pertaining to motherhood and apple pie, 86% favored and 15% opposed. Comments suggested that the split was most probably because of the apple pie and that the question should have been divided. I cite this facetious comment to illustrate the problems faced by some of the committees last evening as they analyzed the initial balloting.

Let me at the outset establish a few parameters. It shall not be my intent to simply reiterate these things which have been so well said by our program participants. Rather, it is my intention to try to catch a common thread and weave that thread, orthogonal in some instances like the weft (woof) and warp in the weave, into an intricately-designed cloth--a tapestry if you will--which defines the direction, and maybe even the rate of change, of engineering education.

To say that we are in a dynamic world would be an understatement. The rate of change of technology is rapidly increasing. There is an increasing complexity, a greater interdisciplinary focus and economic pressures the likes of which we've never seen before. In some areas, engineering education is being led by industry--and in certain subsets--by foreign industry. I've heard some of our speakers say that we need to master the art of change. We must be flexible but coherent. We must be interdisciplinary but maintain the depth demanded by our disciplines. We must be systems-oriented without sacrificing the components which make up the system. But how will we do these things?

We've heard some answers to these questions in this Congress. We will begin by leaning upon our faculties to make it happen. If faculty want something to happen, it will, and vice versa. We must, therefore, make faculty careers more attractive--giving them the distinction of some of our European counterparts--if you please. We will attract the most innovative for our faculty, taking the expertise where we can find it--whether in retirees from industry, in industrial adjuncts or in

the more classical intensively–educated new PhD's. We will insist upon a mix of theory and practice. We must be able to match the peg with the hole, to build better widgets, with a constant reminder that quality and productivity go hand–in–hand. Faculties must interface more with their industrial counterparts in order to see that this happens.

Faculty development must be more than mere words. It must be fostered by the academy, but individual faculty must assume the primary responsibility for arranging their own professional development. We preach to our students the need for continuing education, for sustained professional development, while oftentimes complaining that burgeoning enrollments and heavy loads keep our faculties from personal professional growth. Faculty who excel stay on the forefront, on the cutting edge. And administrators must gently nudge––dangle the carrot rather than use the stick, pat on the back rather than kick the tail.

We can instantly increase the attractiveness of our graduate programs by improving stipends. You've heard the numbers––make the stipends equal to at least half of the starting salaries of the B.S. graduates, especially for the Ph.D. students. This will attract more of our high–quality American students and increase the cosmopolitan features with respect to some very fine international graduate students.

We've heard a lot of words about effective teaching; and, with the possible exception of some isolated athletic programs, nothing at the academy builds better alumni support than effective teaching. Our graduates appreciate being prepared to face the world, to be able to compete with graduates from the institution down the interstate. But we've neglected the teaching function in the pursuit of research where "dollars in and papers out" get promotion and tenure. We've heard words in this Congress which call upon us to make effective teaching a uniform requirement for promotion and tenure. And we've heard some ways to promote it––with effective teaching institutes and with university–industry interactions. No one should teach that which he/she is incapable of practicing. We can enhance our faculties by maintaining a balance among them, recognizing that not all should participate equally in research, in design projects or in other major aspects of the program. But they should be viewed as a symphony with each person playing his/her own part in a superior way such that the faculty as a whole makes good music together.

Some of our speakers have highlighted the internationalization of our economy and our technology––and rightly so. International competition is forcing worldwide economic restructuring. U.S. technological dominance can no longer be taken for granted. Our curricula must take these realities into account. Too many of our graduates have escaped without being exposed to economics or engineering economy. Too many of our graduates leave without integrating their optimum components into an optimized system. The factories of today are suffering the consequences of this in the pile up of some components while others are being built. We've heard a call for integrating planning, design, budgeting, simulation and control through <u>required</u> interdisciplinary coursework while approaching such efforts via student teams.

But these efforts take time, and our curricula are crammed full. We can make room for them, however, if we heed the call to optimize the engineering sciences stem of our curricula, for example. We can make room for them by making more efficient use of the computer as a tool by integrating its use throughout the curriculum. We may be able to expose our students to broader-based basic sciences, as called for here, if we can optimize the requirements in mathematics, as suggested. It is time that we question the need for such a large dose of non-discrete mathematics. We need to take full advantage of the advent of high-speed, mega-step numerical computation. And, yes, we do need to improve the liberal side of our education. The current national studies are right. But how do we make the time for all of these worthy recommendations?

We've heard some arguments for extending the length of our programs which lead to the first professional degree. And some of us have lived through the great debates of recent years on this subject. But it may be time to debate again, to pose the same questions with different twists, to interrogate the marketplace while optimizing our products. And here I mean not just the products of our engineering education programs, our graduates, but also the products which reach the marketplace--a major optimization process which extends from the "knowledge in" to the "goods out" ends of the spectrum.

In this Congress, we have also heard a proposal to study international accreditation of engineering programs. While 43% of the voters here were neutral on this proposal, I can tell you that ABET has taken a small step in that direction. There is currently an International Accreditation Committee, which met for the first time last night.

We have heard an overwhelming call at this Congress for continued emphasis of engineering design. In my assessment of the proceedings of the past two days, engineering design as been the main character in this drama. It has pervaded every topic and sub-topic. In the views of those who prepared the proposed bill and of those who spoke eloquently on sundry issues, it was engineering design which gave each issue distinction. It is design which distinguishes the engineer from the scientist. It is design which ties us to the marketplace, which gives vent to the creativity of our profession. You have emphasized this as we tied industry to academe. These came to the fore as you called for faculty to have industrial experience. Engineering practice smacks of design as we develop those things which are to benefit mankind. I am personally pleased that you have spoken so heartily in favor of this key curricular component.

Recognizing that the educated person has a broad-based background, you have recommended that the need for broadening courses and for communication skills be examined and strengthened. I heard the need for implementing English proficiency criteria for admission and/or for graduation. You called for the Educational Testing Service's "Test of Spoken English" to be required for all teaching assistants and faculty for whom English is a second language, recommending an acceptable score of 250 out of 300 maximum. While taking that action, I also heard many, publicly and privately, urging that some similar requirement be imposed upon native-English

speakers. But we may be behind on this one since many university boards and state education committees are now requiring that administrators certify that faculty can effectively communicate in English. California just made English the state language. The communication problem has been with us since hieroglyphics. While we may not solve it, it is about time that we work on it some more.

With an eye on limited resources and in an effort to upgrade quality, this Congress has called for: (1) tightening accreditation criteria to dry up weak programs; (2) a moratorium on new Ph.D. programs and (3) a moratorium on new schools of engineering. You've said tighten admissions requirements, forcing the secondary schools to do a better job. You called for larger minimum sized faculties to be sure that programs are fully covered. And you said license the faculty who teach design topics which relate to the safety and welfare of our citizenry.

You think that each curriculum should develop an ideal model program as an incentive for institutions to build quality. And you have called for building more bridges between industry and academe by having advisory committees in each educational unit made up of practicing engineers.

A revolution has been underway in recent years in the laboratory, especially in computation and control. Even in measurements, we've had to change our thinking, depending more upon statistical inference as close tolerancing has become impossible to measure in this era of fits meshing within 50 millionths of an inch. Computers and microprocessors become obsolescent in about 3 years, and many no longer buy service contracts on micro units, choosing rather to cannibalize on throw away units as they become nonfunctional.

Hands–on laboratories continue to be necessary for the engineering student. And the faculty member must remain central to effective lab experiences. Technology should be used for enhancing the laboratory experience, notably in simulation. But direct experimentation will remain an absolute necessity in the future.

Participants in this Congress would urge industry to continue––and even expand––its support for laboratory and computing equipment. We would also hope to get some donated maintenance and service for it––perhaps even going so far as to train the academy's technicians for servicing the equipment. The Congress called for industrial support of general lab equipment similar to that which has been done in computers. There was strong support for using major lab facilities on a regional basis.

In the discussion periods on Laboratories, Computers and Educational Technologies, it seemed obvious that there was a general sentiment of appreciation for the thorough job done by the committee. But it was equally obvious that there was an uneasiness on quantification and specificity. The disagreement on whether the proposed quantification of lab requirements (6.25% of the total program) involved double counting of some engineering science/engineering design courses has been resolved this morning.

As a result of this Congress, every segment of our profession now has a full agenda. It is incumbent upon us to begin the debates, to wrestle with the issues and to make a fine profession even better.

I've very carefully stayed away from editorializing. But here at the conclusion, I'm going to take license. In my opinion, this Congress has been very healthy for engineering education. It will inevitably improve all of engineering. To admit our problems is to begin to solve them. To hear respected colleagues pose potential solutions while being willing to be shot at in the process is a giant step toward their solution. A meeting such as this makes me even prouder of our profession.

Mr.Chairman, I have only one regret--that my wife is not here. For 33 years, I've been telling her that I would someday get the last word!

NCQE

APPENDIX B

Resolutions and Voting

BROAD ACADEMIC ISSUES

Based on the preliminary voting on the Broad Academic Issues presented to the NC2E participants, nearly half of the presented issues passed with acceptable consensus. The resolutions are numbered in the order of their presentation for voting and are worded as presented. Each resolution is followed by the percentage results of the voting on that resolution. Due to rounding, percentages may not total exactly 100%.

SD = Strongly Agree GA = Generally Agree N = Neutral
GD = Generally Disagree SD = Strongly Disagree

#1 LIMITING PROGRAMS

It is recommended that engineering accreditation requirements be enhanced to reflect the desirability of concentrating programs in major centers of learning, thus eliminating many marginal programs, with the view to increase substantially the effectiveness of programs by increasing their faculty strength, curricula and facilities.

SA(19%) GA(28%) N(10%) GD(17%) SD(26%)

#2 MORATORIUM ON NEW PhD PROGRAMS

It is recommended that a moratorium be instituted in the formation of new PhD programs in engineering.

SA(25%) GA(28%) N(7%) GD(17%) SD(22%)

#3 MORATORIUM ON NEW SCHOOLS

It is recommended that a moratorium be declared on the creation of additional schools of engineering.

SA(31%) GA(22%) N(10%) GD(18%) SD(19%)

#4 FACULTY AND LABORATORY REQUIREMENTS

It is recommended that the accreditation requirements for number of faculty members be increased to provide adequate numbers of faculty for instruction and laboratory course work.

SA(32%) GA(41%) N(9%) GD(11%) SD(%7)

#5 ADMISSION REQUIREMENT

It is recommended that college of engineering admission standards be set at a level that will require adequate secondary school preparation in science, mathematics and verbal skills to allow admitted students to enter directly into the engineering program without any college remediation in those subject areas.

SA(39%) GA(34%) N(6%) GD(12%) SD(9%)

#6 REGISTRATION FOR TEACHING

It is recommended that faculty who teach design or topics related to safety and protection of the public be licensed professional engineers.

SA(30%) GA(26%) N(7%) GD(15%) SD(23%)

#7 ADVISORY COMMITTEES

It is recommended that an advisory committee of practicing engineers be mandated in each engineering educational unit.

SA(33%) GA(42%) N(9%) GD(8%) SD(9%)

#8 QUALITY GOALS

It is recommended that each discipline develop an ideal model program and offer this as an incentive to educational institutions in their own assessment of direction and attainment of quality goals.

SA(21%) GA(35%) N(12%) GD(22%) SD(10%)

#9 UNIVERSITY ENVIRONMENT

ABET should carefully monitor the teaching of the design, laboratory, and the practical aspects of engineering programs and the qualifications of the faculty who teach these courses. Quantity and quality of the experience in these areas and the attitudes of the faculty toward the practice of engineering are particularly important. Also, ABET should strongly recommend to institutions that they seek a proper balance between teaching, research, and service in their tenure and promotion criteria toward satisfying the needs of the profession as expressed by industry, professional societies, and the societal needs. ABET should continue to

seek strong industry participation and also participation from our leading research institutions.

SA(35%) GA(41%) N(10%) GD(6%) SD(7%)

#10 CONTINUING EDUCATION

ABET should continue its current efforts and experiments in assessing the quality of continuing education efforts by those that request such aid. It should cooperate with engineering societies, the National Science Foundation, universities and companies in setting objectives of programs, assessing the long term benefits and effectiveness. Outside funding should continue to be sought to carry out these parts of continuing education planning and assessment that fall within the charge of ABET from the participating bodies.

SA(24%) GA(41%) N(14%) GD(12%) SD(9%)

#11 COMPETITIVENESS

It is recommended that steps be taken through major resource support to the engineering educational enterprise to restore economic competitiveness to the U.S. in the international arena.

SA(65%) GA(28%) N(5%) GD(1%) SD(1%)

#12 NATIONAL SCIENCE BOARD

This National Congress on Engineering Education commends the National Science Board for its report on *Undergraduate Science, Mathematics and Engineering Education* and strongly supports its conclusions and recommendations. Further, it endorses the Workshop on Engineering recommendations on directions for carrying out the improvements in engineering education. We agree that serious problems, especially problems of quality, have developed during the past decade in the infrastructure of college-level education in the United States in engineering. There are deficiencies in laboratory instruction, design, and innovation instruction and other areas. In the 1985-86 accreditation cycle, only 28 percent of the programs examined by ABET achieved the maximum accreditation period. This has dropped from its traditional level of 55 percent prior to 1980. At the same time, the "not-to-accredit" and "probationary" actions doubled to 21 percent. This is but one indicator of the deterioration of the quality of undergraduate engineering education.

In 1982, support for edueation efforts dropped to zero from its traditional 25 percent of the National Science Foundation (NSF) budget. We vitally need the leadership of the NSF to aid in the improvement of undergraduate engineering education. While the funds recommended are far from that necessary to solve all the problems of engineering education, we believe that NSF funds will be the catalyst for institutions, states, and industry to join with NSF in solving the current problems. Thus, the funds will be multiplied many fold.

The need is urgent if the United States is to maintain and improve its ability to compete in the world marketplace. Engineering is the keystone to innovation, product development, and improved manufacturing processes in every industry. We have the confidence that the United States can recover its reputation for quality with our own citizens as well as in the community of nations with some stimulation from the right sources. The engineering profession, represented by the 23 engineering societies, with over a million members, which constitute the consortium known as ABET to oversee the quality management in engineering education, call upon the NSF, the President of the United States, and the Congress to carefully analyze the need and support engineering education improvements at this time. The need is urgent!

SA(61%) GA(26%) N(12%) GD(1%) SD(0%)

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The following resolutions were rewritten and presented again during the final, concluding session of NC2E. They are shown here as rewritten, followed by the percentage results of the Session IV voting. Resolution #6 was further modified from the floor during this session and was presented in two versions. Several of these resolutions did not receive clear majorities (positive or negative), which reflects on the mixed opinions currently present in the engineering community on these issues.

The resolutions are shown below in order of their presentation. In addition, two new resolutions were presented at the end of Session IV and are shown as the last two Broad Academic Issues resolutions.

#D1 (#1) LIMITING PROGRAMS

It is recommended that engineering accreditation minimum requirements be raised to increase the quality of programs and their graduates; this would force marginal programs to be eliminated, or to get the resources needed to improve faculty strength, curriculum and facilities.

SA(23%) GA(29%) N(9%) GD(18%) SD(21%)

#D2 (#2) **MORATORIUM ON NEW PhD PROGRAMS**

It is recommended that engineering schools with limited resources, which have a primary orientation to undergraduate education...

a) be encouraged not to institute new PhD programs, and

b) be encouraged to eliminate small PhD programs.

SA(13%) GA(24%) N(5%) GD(23%) SD(36%)

#D3 (#3) **MORATORIUM ON NEW SCHOOLS**

Given the shortage of qualified engineering faculty and the limited resources to maintain laboratory and other facilities in existing schools, it is recommended that a moratorium be declared on the creation of additional schools of engineering.

SA(21%) GA(20%) N(7%) GD(19%) SD(34%)

#D4 (#6) **REGISTRATION FOR TEACHING** (First Version)

It is recommended that faculty who teach design related to safety and protection of the public be registered professional engineers.

SA(28%) GA(18%) N(2%) GD(19%) SD(32%)

#D5 (#8) **QUALITY GOALS**

It is recommended that each discipline develop an ideal model program and offer this as an incentive to educational institutions in their own assessment of direction and attainment of quality goals.

SA(10%) GA(27%) N(6%) GD(32%) SD(25%)

#D6 (#10) **CONTINUING EDUCATION**

ABET should continue current efforts and experiments in assessing the quality of continuing education efforts by those that request such aid.

SA(18%) GA(48%) N(11%) GD(12%) SD(11%)

#D7 (#13) **MINORITIES, WOMEN**

It is recommended that ABET review engineering school efforts to increase the enrollment, retention, academic performance, and graduation rate of minorities and women, during accreditation visits.

SA(19%) GA(28%) N(6%) GD(21%) SD(26%)

#D8 (#14) **DOCTORATE OF ENGINEERING AS FIRST PROFESSIONAL DEGREE**

This resolution was originally presented during Session II on Curriculum Issues. It was rewritten as a Broad Academic Issue and presented to the participants.

It is recommended that ABET form a study committee to explore the doctorate of engineering as the first professional degree.

SA(12%) GA(23%) N(10%) GD(15%) SD(40%)

#D9 (#6) **REGISTRATION FOR TEACHING (NCEE Version)**

It is recommended that faculty who teach design and professional subjects be registered professional engineers.

SA(25%) GA(12%) N(4%) GD(17%) SD(43%)

CURRICULUM ISSUES

The following resolutions were presented during NC2E Session II on Curriculum Issues. Of these, the first ten issues received the consensus endorsement of the NC2E delegates. Three resolutions (13II, 13IV, & 18) were not adopted by NC2E based on the large percentages of negative votes cast. This session's resolutions, the most numerous of all the sessions, are numbered in the order of their presentation for voting and are worded as presented. Each resolution is followed by the percentage results of the voting on that resolution. Due to rounding, percentages many not total exactly 100%.

SA = Strongly Agree GA = Generally Agree N = Neutral
GD = Generally Disagree SD = Strongly Disagree

#1 **COMPUTER USE**

In order to enhance engineering education through computer use, the accreditation criteria for computer use in engineering curricula should be

strengthened so as to require institutions to demonstrate that computer use is an effective part of the instructional program. Faculty proficiency should be enhanced by in-house mandatory training of faculty and review of course utilization if necessary. Further, significant effort should be devoted by industry and government to assist with resources for adequate training, curricula improvement, and computer availability for all engineering students.

SA(49%) GA(41%) N(6%) GD(2%) SD(1%)

#2 MANUFACTURING AND CONSTRUCTION

In as much as most engineering disciplines are involved in manufacturing and construction to some degree, every effort should be made to focus on the integration of design, planning, simulation, and control into all engineering curricula through required interdisciplinary coursework. Such coursework should foster the importance of interdisciplinary team efforts to solve engineering problems, particularly manufacturing and construction problems.

SA(30%) GA(50%) N(11%) GD(7%) SD(2%)

#3 BASIC SCIENCE REQUIREMENT

The accreditation criteria for the basic science area should be expanded so as to include basic science electives of the students' choice as part of the required coursework to add breadth to science coverage. Institutions should be encouraged to experiment with new science sequences to give more breadth and preparation for the emerging fields of interest for engineering application, such as biotechnology, information sciences, geotechnology, and advanced materials applications.

SA(29%) GA(49%) N(12%) GD(8%) SD(2%)

#4 MATHEMATICS REQUIREMENT

The accreditation criteria for the mathematics areas should be revised to ensure that students have some training in probability, statistics, and numerical analysis as part of the required sequence. Experimentation in methods of mathematics presentation, sequence of courses and coverage should be encouraged to see if more efficiency in knowledge transmission can be achieved.

SA(46%) GA(47%) N(3%) GD(2%) SD(2%)

#5 THE GLOBAL ECONOMY

Engineering education programs should include an emphasis on technical areas which strongly impact the competitive posture of the United States in foreign markets. Such areas might include robotics, manufacturing processes, microcomputers, statistics, quality control, and inspection, as well as many others. Particularly important is the emphasis on those parts of the curriculum that develop creativity, innovation, systems, and design attributes in the student to develop products of quality to compete in global competition.

SA(24%) GA(43%) N(18%) GD(9%) SD(5%)

#6 THE INDUSTRIAL ENVIRONMENT

Engineering programs should include, at an appropriate level, some study of engineering cost analysis, project management and organization, resource budgeting, and leadership theory and practice.

SA(34%) GA(45%) N(11%) GD(6%) SD(4%)

#7 ENGINEERING SCIENCE CRITERIA

Traditional engineering curricula should be carefully reviewed in terms of content so as to optimize existing courses and make room in the curricula for new areas. More emphasis should be placed upon breadth of coverage, particularly in engineering sciences, to aid the student in understanding interdisciplinary concepts. Institutions should be encouraged to experiment with a variety of programs and report the results.

SA(30%) GA(46%) N(16%) GD(6%) SD(2%)

#8 BASIC EDUCATION REQUIREMENT

The broadening courses and the communication skills courses associated with reading, speaking and writing should be studied via a task force with the goal of taking the initiative away from the Liberal Arts faculty and in determining what best makes sense for our engineering programs. We should be willing to put in place firm requirements to insure that all students do have the desired breadth regardless of the number of courses which are required.

Engineering curricula should include specific engineering courses which incorporate written, oral, graphical, and interpersonal communication skills, and these areas should be emphasized in the evaluation of student

performance. It also would be useful to consider the development and implementation of English proficiency criteria as part of the admission and graduation criteria. It would be appropriate to establish an ABET study committee to review and revise the existing communication skill criteria.

SA(32%) GA(39%) N(13%) GD(9%) SD(7%)

#9 ENGINEERING DESIGN CRITERIA

ABET should continue its current emphasis, intensifying effort if possible, on the design, innovation, and creativity requirements of engineering programs as described in the accreditation criteria. Furthermore, ABET should encourage experimentation by institutions to find better ways of teaching this emphasis. Such programs should continue to include considerations of economic factors, safety, reliability, aesthetics, ethics, and social impact. Quality of the design experience is more important than the quantity ABET requirements now being used. However, a comprehensive design experience is essential to all engineering programs since design ability, in the broadest sense, is the main attribute which characterizes the engineer from the scientist.

SA(52%) GA(39%) N(4%) GD(4%) SD(2%)

#10 LIBERAL ARTS AND HUMANITIES

The humanities social science component of the various engineering programs should be expanded and be more carefully monitored so that optimal use is made of this time in accord with the criteria which require that the program "reflect a rationale or fulfill an objective appropriate to the engineering profession and the institution's educational objectives." Current needs to understand world economics should lead to positive consideration of economics, international relations, and second language courses for some students. The humanities/social sciences requirement in the ABET criteria is often a carelessly administered area, and it deserves more attention from both the engineering faculties and students. Further, engineering colleges should work closely with the liberal studies faculties to carefully choose and/or design course sequences to utilize the available time effectively.

SA(30%) GA(47%) N(10%) GD(7%) SD(6%)

#11 INTERNATIONAL ACCREDITATION

In order to clarify the potential for international accreditation of engineering programs, an ABET study committee should be appointed to

develop a plan for pursuing the establishment of international accreditation criteria.

SA(16%) GA(19%) N(39%) GD(11%) SD(15%)

#12 PROFESSIONAL LEVEL ACCREDITATION

In order to identify the appropriateness of a Professional Level Accreditation procedure for this category, it is recommended that ABET establish a study committee to review the extent to which a problem exists in non-engineers obtaining graduate engineering degrees with limited or no education in the engineering fundamentals and develop criteria to allow them to qualify more expeditiously for registration as professional engineers.

SA(18%) GA(36%) N(18%) GD(12%) SD(15%)

#13I ENCOURAGE FIVE-YEAR PROGRAM

In view of the increased emphasis on a broad education for engineering students, it appears that a five-year program will be necessary to provide sufficient breadth and depth in engineering education subjects to adequately qualify to enter an engineering career at the professional level. ABET and the engineering community should encourage the educational programs to develop a five-year program as the first professional engineering degree (approximately 160 semester credit-hours, in current measurement criteria).

SA(17%) GA(19%) N(6%) GD(21%) SD(37%)

#13II REDUCE TECHNICAL CONTENT

In view of the increased emphasis on a broad education for all university students, the number of technical subjects should be reduced in order to provide a basic engineering education program in four years. It should be recognized that graduates will be adequately prepared for many jobs, but with limited depth for true engineering applications. Those students desiring to practice engineering at their professional level would be obligated to attend graduate school to obtain their first professional degree. The four-year program would as a consequence be less specialized, delaying specialization in depth to the fifth year.

SA(9%) GA(16%) N(9%) GD(22%) SD(44%)

#13III REINSTITUTE DUAL-LEVEL

ABET should reinstitute graduate level/advanced level accreditation, more carefully designed than the past experiment, to create dual level accreditation and encourage a longer period of study in a transitional era toward making a longer period of study the norm. In this way institutions are not forced to choose between levels and jeopardize their market without testing the format.

SA(18%) GA(19%) N(16%) GD(14%) SD(33%)

#13IV PRESCRIBE 5-YEARS BY 1995

ABET should advise the National Council of Engineering Examiners that a five-year engineering education program is the minimum program that qualifies a person for entry into the profession of engineering, and by the year 1995 it will only accredit five-year programs for this purpose. These preferably should be five-year integrated programs leading to a master's degree, but properly designed programs of a "4+1" or "3+2" character would also be permissible.

SA(18%) GA(12%) N(9%) GD(16%) SD(45%)

#14 REQUIRE STATISTICS

Appropriate knowledge and practical experience of statistical experimental design data analysis and quality measurement technology must be an integral part of every engineering program. Such practices should be infused throughout the engineering curricula along with some formal coursework in these applied statistics areas. These practices should be an integral part of all laboratory experiences. Appropriate statistical design and reliability should be incorporated in the engineering design requirements.

SA(23%) GA(44%) N(15%) GD(7%) SD(10%)

#15 REQUIRE HEALTH AND SAFETY

We recommend that Resolution #6 on the industrial environment be revised to include health and safety factors as an additional study subject and secondly, Resolution #9 on the engineering design criteria should also be revised to replace the word "safety" with the broader concept of "protecting and occupational safety and health".

SA(15%) GA(34%) N(26%) GD(15%) SD(9%)

#16 LANGUAGE ADMISSION REQUIREMENT

We recommend an increase in engineering education admission requirements by requiring a foreign language and, secondly, by requiring excellent English language skills, both oral and written.

SA(13%) GA(31%) N(21%) GD(14%) SD(21%)

#17 ORIENTAL LANGUAGES AS ELECTIVES

Engineering education should offer as electives Japanese and Chinese language and culture, particularly Mandarin and Russian language and culture.

SA(9%) GA(30%) N(27%) GD(15%) SD(19%)

#18 DOCTOR OF ENGINEERING AS PROFESSIONAL DEGREE

The doctorate of engineering should be the first professional degree, based on four years of liberal arts pre-engineering where the math, science, social science, and humanities requirements of ABET will be met and on three years of past-baccalaureate work where engineering science, engineering design and engineering internship experiences would occur. At the end of that period of time, one would be granted the doctorate of engineering degree.

SA(7%) GA(11%) N(16%) GD(18%) SD(48%)

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Based on the voting conducted during Session II on Curriculum Issues, the following resolutions were rewritten and presented again for voting during Session IV. They are shown here as rewritten, followed by the percentage results of the Session IV voting. Several of these resolutions did not receive clear majorities (positive or negative), which reflects on the mixed opinions currently present in the engineering community with regard to curriculum issues. The resolutions are shown below and include the original resolution number to facilitate cross-referencing.

#B1 (#11) INTERNATIONAL ACCREDITATION

In order to clarify the potential for international accreditation of engineering programs, an ABET study committee should be appointed to

develop a plan for pursuing the establishment of international accreditation criteria.

SA(16%) GA(21%) N(25%) GD(15%) SD(24%)

#B2 (#12) PROFESSIONAL–LEVEL ACCREDITATION

In order to identify the appropriateness of a professional–level accreditation procedure for this category, it is recommended that ABET establish a study committee to review the extent to which a problem exists in non–engineers obtaining graduate engineering degrees with limited or no education in the engineering fundamentals and develop criteria to allow them to qualify more expeditiously for registration as professional engineers.

SA(19%) GA(33%) N(11%) GD(20%) SD(17%)

#B3 (#14) REQUIRE STATISTICS

We recommend that a specific statement be included under the ABET requirements for "Curricular Objective and Content" [ed. note: See ABET publication #AB–7, *Criteria for Accrediting Programs in Engineering in the United States*, Section 2.(4).] to be placed along with sections "e." (Laboratory Experience) and "f." (Computer–based Experience) as follows:

"Appropriate knowledge and practical experience of statistical experimental design, data analysis and quality management technology must be an integral part of every engineering program.

"Such practices should be infused throughout the engineering curricula along with some formal coursework in these applied statistics areas.

"These practices should be an integral part of all laboratory experiences.

"Appropriate statistical principles including concepts such as statistical experimental design and reliability should also be incorporated in the engineering design requirements."

SA(23%) GA(38%) N(5%) GD(18%) SD(16%)

#B4 (#15) HEALTH AND SAFETY

Existing courses should be strengthened to include practical instruction on responsibilities in:

- Manufacturing and Construction Include course materials that inform students of their responsibilities in such areas as product liability, quality control, applicable standards, regulatory aspects, and professional liability considerations.

- The Industrial Environment As in the subject above, there is a need to incorporate instruction on safety and health responsibilities in the education process. The engineer will face these issues in the business/industrial climate.

- Engineering Design Accreditation Criteria Under current criteria, it is desirable to include constraints such as –safety, reliability–. We submit that these constraints should be essential not desirable.

SA(28%) GA(41%) N(6%) GD(15%) SD(11%)

#B5 (#16) FOREIGN LANGUAGE ADMISSION REQUIREMENT

Require for admission to an engineering program the introduction to a foreign language.

SA(14%) GA(22%) N(9%) GD(25%) SD(30%)

#B6 (#16) MASTERY OF ENGLISH REQUIREMENT

Require as admission to an engineering program the mastery of the English language.

SA(36%) GA(31%) N(7%) GD(12%) SD(13%)

#B7 (#17) REQUIRE LANGUAGE AND CULTURE OF JAPAN, CHINA OR RUSSIA

Require the language and culture of Japan, China or Russia as a required course.

SA(4%) GA(14%) N(13%) GD(19%) SD(50%)

#B8 (#131) ENCOURAGE FIVE-YEAR PROGRAM

In view of the increased emphasis on a broad education for engineering students, it appears that a five-year education program will be necessary to provide sufficient breadth and depth in engineering education subjects to adequately qualify to enter an engineering career at the professional level. ABET and the engineering community should encourage the

educational programs to develop a five-year program as the first professional engineering degree, recognizing that many programs will continue to graduate technically oriented people in four years.

SA(28%) GA(21%) N(5%) GD(18%) SD(29%)

#B9 (#13III) REINSTITUTE DUAL-LEVEL

ABEt should reinstitute dual-level accreditation with different criteria than the past experiment to encourage a longer period of study in a transitional era toward making a longer period of study the norm for professionally oriented graduates. In this way institutions are not forced to choose between levels and jeopardize their market without testing the format.

SA(24%) GA(25%) N(8%) GD(16%) SD(27%)

FACULTY ISSUES

The following resolutions were presented during NC2E Session I on Faculty Issues. Four resolutions met with mixed results and were sent back to the committee. The committee then studied the comment sheets and altered the four resolutions accordingly for presentation again during Session IV. The resolutions are numbered in the order of their presentation for voting and are worded as presented. Each resolution is followed by the percentage results of the voting on that resolution. Due to rounding, percentages may not total exactly 100%.

SA = Strongly Agree GA = Generally Agree N = Neutral
GD = Generally Disagree SD = Strongly Disagree

#1 INCREASING ATTRACTIVENESS OF GRADUATE PROGRAMS

Engineering students are motivated to seek a career devoted to the creation of useful goods and services. Many are not motivated by a career in science or research. Since many engineering educators have been largely selected for their research ability and tend to replicate themselves, some engineering students are turned off by a science and research oriented educational experience. Those students recognizing that most engineering graduate work is research directed find no motivation in graduate work and the faculty career for which it is prerequisite.

The development and recruitment of professionally competent graduate students and faculty would be enhanced by the selection of faculty on the basis of education for professional competence and engineering practice.

SA(27%) GA(46%) N(15%) GD(9%) SD(4%)

#2 GRADUATE SUPPORT

A major increase in fellowship support and concomitant engineering college research support are needed to attract more of the very brightest U.S. citizens into graduate programs in engineering. To attract top students into graduate work, doctoral fellowships should carry stipends equal to at least half the starting salary of a new B.S. graduate.

SA(56%) GA(33%) N(6%) GD(4%) SD(1%)

#3 PROFICIENCY IN ENGLISH

We recommend that the "Test of Spoken English" administered by the Educational Testing Service be required of all teaching assistants and new faculty members for whom English is a second language. A score of 250 (out of 300 maximum) is recommended as an acceptable score.

SA(60%) GA(26%) N(4%) GD(6%) SD(5%)

#4 THE TEACHING FUNCTION

Universities and colleges should be diligent in maintaining the integrity and effectiveness of the teaching function. In no case should tenure be granted unless there is clear evidence of ability and effectiveness in teaching. Similar evidence should be required at each subsequent evaluation to ensure that teaching effectiveness is maintained throughout a faculty member's professional life.

SA(62%) GA(28%) N(4%) GD(4%) SD(1%)

#5 WORKSHOPS FOR EFFECTIVE TEACHING

It should be the responsibility of the hiring institution to provide guidance and assistance in effective teaching by recommending and/or sponsoring appropriate seminars, workshops, or institutes. Educational institutions

should offer a pre-service or in-service workshop for faculty members, including adjunct or part-time faculty.

SA(40%) GA(47%) N(12%) GD(1%) SD(0%)

#6 ENGINEERING PRACTICE

Engineering schools should seek to employ faculty with demonstrated professional competence in the practice of engineering. This applies to research universities as well as to others. With the increasing tendency for industry to lead academia in some research fields, and with the increasing tendency for industry to employ engineers with graduate degrees, the need for close relationships between industry and academia becomes stronger than ever.

We recommend that, before senior faculty status is attained, engineering faculty should have accumulated a minimum of two years of experience related to the function of providing innovative products, methods, processes, or services of an advanced nature. This experience may be gained through a sabbatical in industry, a series of summer jobs, through consulting, by supervising industrially-sponsored research contracts, or some combination thereof. Familiarity with industry or with other relevant professional practice should be kept current.

SA(40%) GA(35%) N(8%) GD(11%) SD(7%)

#7 BALANCED COMPOSITION OF ENGINEERING DEPARTMENTS

In building faculty within an engineering department, strong attention should be given to the balance of faculty background, attitudes, and experience. The faculty composition, in addition to teaching, should address the following issues of balance: science, engineering practice, design analysis, strong professional experience, research.

SA(41%) GA(43%) N(12%) GD(2%) SD(1%)

#8 ENHANCING THE ATTRACTIVENESS OF FACULTY CAREERS

In order that the very best engineering students can be attracted to faculty positions, the quality of life of the engineering faculty member must be improved. The quality of life can be improved in many ways. The most obvious are providing the engineering faculty member with a teaching load that is reasonable, providing the faculty with time for

library and computer studies, providing modern engineering experimental facilities, and competitive compensation.

SA(59%) GA(30%) N(6%) GD(4%) SD(1%)

#9 MAINTENANCE OF PROFESSIONAL COMPETENCE

Just as engineering practitioners need to preserve and enhance their professional competence throughout their careers, engineering faculty members must stay current with their technical fields and with educational developments. We recommend that:

- Individual faculty members assume the principal responsibility for arranging their own professional development.
- Engineering college administration take the responsibility for making available structured professional development.
- Employer organizations provide developmental work assignments for engineering faculty members.

SA(37%) GA(39%) N(10%) GD(10%) SD(4%)

#10 UNIVERSITY–INDUSTRY INTERACTION

In order to enhance U.S. competitiveness, we strongly endorse increased emphasis on advanced development university research projects that are cooperatively sponsored and jointly sponsored by state and federal agencies and industry. Such projects should be of a broad nature and should contribute to curriculum and faculty development.

SA(57%) GA(33%) N(8%) GD(2%) SD(0%)

#11 UTILIZE FACULTY WITHOUT DOCTORATE DEGREES

Schools that emphasize an undergraduate education can utilize many faculty who do not have doctoral degrees. Universities with significant graduate research programs will also be able to utilize some non–doctoral faculty.

SA(30%) GA(31%) N(15%) GD(15%) SD(8%)

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During Session I on Faculty Issues, the following resolutions met with strong differences of opinion. These resolutions were subsequently rewritten and presented again for voting during Session IV. They are shown here as rewritten, followed by the percentage results of the voting during Session IV. While the degree of disagreement on these four resolutions is greater than those passed in Session I, a clear majority exists in all cases.

#A1 GRADUATE PROGRAM ATTRACTIVENESS

The development of professionally competent graduate students would be enhanced by the selection of some faculty on the basis of education and demonstration of competence through experience in professional practice. The graduate school experience should contain options in engineering science, applied research, and engineering practice. The need is for a well-balanced graduate program and faculty.

SA(44%) GA(42%) N(4%) GD(6%) SD(4%)

#A2 PROFICIENCY IN ENGLISH

We recommend that the "Test of Spoken English" administered by the Educational Testing Service be required of all teaching assistants and new faculty members (for whom English is a second language). A score of 250 (out of 300 maximum) is recommended as an acceptable score.

SA(42%) GA(24%) N(3%) GD(8%) SD(23%)

#A3 MAINTENANCE OF PROFESSIONAL COMPETENCE

Just as engineering practitioners need to preserve and enhance their professional competence throughout their careers, engineering faculty members must stay current with their technical fields and with education developments. We recommend that:

- Individual faculty members assume the principal responsibility for arranging their own professional development.
- Engineering college administration take the responsibility for making available structured professional development.
- Employer organizations provide developmental work assignments for engineering faculty members.

SA(52%) GA(39%) N(5%) GD(2%) SD(2%)

#A4 UTILIZING FACULTY WITHOUT DOCTORATE DEGREES

Schools that emphasize undergraduate education can utilize many faculty who do not have doctor's degrees. Universities with significant graduate and research programs will also be able to utilize some nondoctoral faculty in special roles. However, the faculty in such "research universities" should, in the overwhelming majority, have doctor's degrees.

SA(45%) GA(40%) N(4%) GD(6%) SD(7%)

ISSUES ON LABORATORIES, COMPUTERS AND EDUCATIONAL TECHNOLOGY

Based on the preliminary voting during NC2E Session III on Laboratories, Computers and Educational Technology, the following resolutions received the agreement of the NC2E participants. Only one resolution was rewritten and presented again during Session IV. The resolutions are numbered in the order of their presentation for voting and are worded as presented. Each resolution is followed by the percentage results of the voting on that resolution. Due to rounding, percentages may not total exactly 100%.

SA = Strongly Agree GA = Generally Agree N = Neutral
GD = General Disagree SD = Strongly Disagree

Appropriate Role of Technology in Engineering Education

#1 FOCUS ON TEACHING

The teacher must continue to be the primary focus of the educational activity, but today's technology should be used to enhance the teaching process by giving the teacher new tools for calculation, for simulation, and for display.

SA(76%) GA(22%) N(1%) GD(0%) SD(0%)

#2 LABORATORY EXPERIENCE

Laboratory experience is a vital component of engineering education with a sound pedagogic foundation and clear relevance to successful practice. It should be a component of every undergraduate engineering program. A variety of modes for laboratory instruction is being used, and should be

encouraged. Computer–based simulation can be combined effectively with direct experimentation in such programs.

SA(74%) GA(26%) N(0%) GD(0%) SD(0%)

#3 LIBRARY

The conventional library has long been recognized as an essential resource for the student. The collection, delivery and processing of information using today's technology is a powerful new resource which must be made available to the student in as broad and diverse a form as possible.

SA(61%) GA(35%) N(4%) GD(0%) SD(0%)

#4 LIFE–LONG LEARNING

More than even before, the education of the engineer must be a lifetime process. This requires techniques and skills which are necessary for the effective use of continuing education. The needs of the mature individual to maintain competence as well as the focus on a new area of study should be anticipated in undergraduate education. Educational technologies such as instructional television (ITV) and combination of television and computers should be introduced to undergraduates because these show great promise in assisting life–long study.

SA(62%) GA(29%) N(4%) GD(4%) SD(1%)

Resource Allocations

#1 INDUSTRY FINANCIAL SUPPORT

Industry is urged to continue its financial support for laboratory and computing equipment. Recent marked improvements in these areas of engineering education reflect the growth of this support.

SA(69%) GA(28%) N(1%) GD(1%) SD(0%)

#2 COMPUTER MAINTENANCE

Cooperative efforts should be made to develop new approaches for maintenance of computer hardware and software, otherwise the task probably cannot be accomplished.

SA(64%) GA(28%) N(5%) GD(1%) SD(1%)

#3 DONATED EQUIPMENT

Laboratory equipment donated by industry can be an important source which has not been exploited to the degree recently experienced with computers. Efforts to acquire laboratory equipment other than computer equipment should continue to be a high priority donation request.

SA(52%) GA(38%) N(6%) GD(3%) SD(0%)

#4 REGIONAL UTILIZATION OF LABORATORIES

Efforts should be made to improve regional sharing of major experimental facilities on a collective basis.

SA(18%) GA(33%) N(29%) GD(13%) SD(8%)

#5 INDUSTRIAL TRAINING OF TECHNICAL STAFF

Laboratory equipment donated by industry must be operated by trained personnel. Industry is urged, when making such donations, to either include a trained technician to operate the equipment, or to train without charge, an operator from the college staff.

SA(31%) GA(40%) N(20%) GD(4%) SD(4%)

Accreditation Criteria

#1 LABORATORY REQUIREMENT

In recognition of the fact that motivated faculty, given adequate time and resources, constitute the keystone of a successful laboratory program, ABET criteria should examine programs to gather evidence of:

1) faculty being encouraged and rewarded for providing a dynamic laboratory experience, and

2) adequate division of faculty time to allow them to fully plan and prepare laboratory instruction.

SA(35%) GA(44%) N(10%) GD(6%) SD(6%)

#2 COMPUTER REQUIREMENT

In recognition of the fact that the computer has become the primary administrative tool for engineering education and that the computer has also added major new educational dimensions through graphics and text manipulation, ABET criteria should examine the commitment of engineering programs to:

1) adequate division of faculty time and resources to allow faculty to fully plan and prepare computer enhancements and their integration into engineering programs, and

2) faculty encouragement and reward for integrating the computer into coursework in an innovative and dynamic manner.

SA(31%) GA(47%) N(10%) GD(6%) SD(6%)

#3 "STRAWMAN" OF ABET CRITERIA FOR LABORATORY AND COMPUTER EXPERIENCE

Criteria – Laboratory and computer experience is a valuable part of engineering education. Evidence of program commitment to this principle consists of the following:

1) curricular requirements for a mix of several forms of laboratory and computer experience at or above the levels described below;

2) availability of appropriate equipment and space resources to meet these requirements; and

3) assignment of responsibility for the provision of laboratory and computer experience to both junior and senior faculty.

Laboratory and computer experience can be provided in several forms. The total experience of an engineering student should include elements from each of the forms given below.

a) Engineering Science Labs – These are customarily structured laboratory courses that help the student to gain physical and mathematical insight into engineering principles. They support and draw from classroom work in the engineering sciences and introduce the student to elementary measurement methods and tools of the engineering professions. Written reports should concentrate on brevity and graphics as a descriptive shorthand. Simple yet elegant concept experience and illustration with conventional professional equipment is the goal.

b) Basic Simulation and Modeling – These are series of computer–based short projects associated with engineering science course work that either simulate physical or mathematical behavior of a system or model a system from experimental data. Written reports should concentrate on well–documented programs and clear graphics or tabular presentation of results. Development of simulation and modeling skill is the goal.

c) Engineering Professional Labs – These are structured lab courses associated with engineering design and advanced engineering professional coursework. Experience should include integration of engineering concepts with substantial and extended work in engineering design, test, and evaluation. Use of modern professional equipment and computer–based data acquisition and analysis is an important part of the professional nature of such lab work and should be emphasized. Written and oral reports should be of the character given to a client who might pay for such work and should reflect the desirable high quality of the client–engineer professional relationship. Experience in the nature and methods of professional experimental engineering work is the goal.

d) Professional Simulation and Modeling – These are computer–based projects of a substantial and extended nature associated with engineering design and advanced engineering professional course work. It is most desirable that such simulation and modeling be linked to Engineering Professional Lab work. Moreover, it is most desirable that this simulation and modeling make use of major engineering analysis and design application programs widely available and in use in the engineering profession today. General familiarity with the ease of use and power of commercially available applications programs is the goal. Written reports should be in the form of standard outputs of such programs and succinct descriptions of the actual applications.

Discussion – Elementary engineering freshman design and introduction to engineering course lab work may qualify for engineering science lab or basic simulation and modeling credit. Engineering CAD courses may qualify for basic simulation and modeling credit.

Bachelor's degree theses, structured co–op work experiences with written reports judged by faculty as well as industrial advisors, and independent study projects culminating in written reports and formal evaluation may qualify for engineering professional lab or professional simulation and modeling work. At all times, the technical reports and presentation should be evaluated on both technical content and clarity.

Guidelines – The member societies of ABET will determine individual minimum guidelines for the quantity and quality of undergraduate laboratory and computer experience in their respective professions. These

individual society guidelines should meet and may exceed these ABET criteria:

1) Undergraduate engineering laboratory and computer experience should consist of a minimum of the equivalent of one–fourth of a year or 6.25 percent of the total semester credit hours required for the baccalaureate degree. Use the appropriate conversion factors for a quarter system program.

2) This minimum experience should contain at least one of each of the four forms of experience described above. The specific mix beyond this requirement is the choice of the individual program except where member societies rule differently.

Member society guidelines in addition to the above will be widely published and available to educational institutions at least four years prior to requirements for curricula to meet such society guidelines.

> (In a related but separate publication, member societies should develop and keep current goals of excellence to guide the development of laboratories and computing facilities.)

The availability of the appropriate equipment and space to meet the laboratory and computer experience requirements is based on the judgement of the individual ad hoc society visitors to a program. It is important in this judgement to evaluate what the individual student actually experiences. Fine equipment may be at hand in the educational institution but not be available to the undergraduate on a regular basis; equipment may not be available in the institution but readily available in co–op industry. Open scheduling of labs or computers may greatly increase the general availability of space and facilities with relatively modest resource investment.

The provision of the laboratory and computer experience opportunities for the undergraduate engineering student is the responsibility of both the junior and senior faculty. Because the time demanded of faculty for the provision of quality lab and computer experience usually exceeds that demanded for the provision of an equivalent amount of classroom course material, it is necessary that academic administration policies recognize, support and adequately reward a strong commitment to laboratory development and maintenance. This commitment should be evidenced in direct faculty design and development of instructional materials and direct faculty supervision of laboratories or close faculty supervision of teaching assistants assigned to laboratory duties.

SA(14%) GA(38%) N(23%) GD(14%) SD(11%)

*****

During Session IV, the committee presented a final resolution that highlighted the focus of their efforts:

#C1 (#4) SPECIFIC CRITERIA

ABET should proceed to develop more specific criteria regarding laboratory, computer and educational technology utilization.

SA(36%) GA(35%) N(4%) GD(14%) SD(12%)

NCQE

APPENDIX C

Summary of Voting Statistics

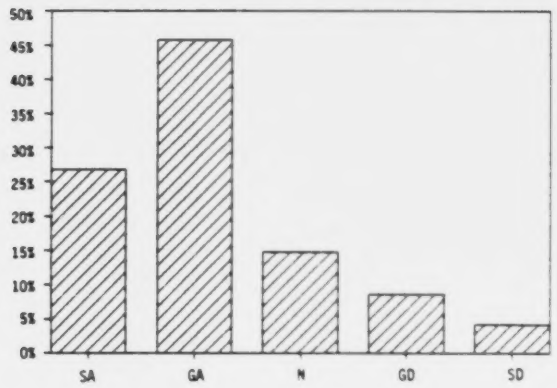
NC2E-NATIONAL CONGRESS ON ENGINEERING EDUCATION
RESOLUTION STATISTICS: BASED ON ALL VOTES RECEIVED

	Number of Votes Cast						% of Votes Cast				
FACULTY RESOLUTIONS	SA	GA	N	GD	AS	TOTAL	SA	GA	N	GD	SD
1. GRADUATE PROGRAM ATTRACTIVENESS	69	118	38	22	11	258	27%	46%	15%	9%	4%
2. GRADUATE SUPPORT	141	95	14	9	2	261	54%	36%	5%	3%	1%
3. PROFICIENCY IN ENGLISH	156	68	10	15	12	261	60%	26%	4%	6%	5%
4. THE TEACHING FUNCTION	160	74	10	10	5	259	62%	29%	4%	4%	2%
5. TEACHING WORKSHOPS	105	120	33	2	0	260	40%	46%	13%	1%	0%
6. ENGINEERING PRACTICE	102	90	20	28	19	259	39%	35%	8%	11%	7%
7. BALANCED DEPARTMENTS	107	116	28	6	3	260	41%	45%	11%	2%	1%
8. FACULTY CAREER ATTRACTIVENESS	156	76	14	10	1	257	61%	30%	5%	4%	0%
9. PROFESSIONAL COMPETENCE	95	101	25	26	11	258	37%	39%	10%	10%	4%
10. INTERACTION WITH INDUSTRY	148	81	21	4	0	254	58%	32%	8%	2%	0%
11. UTILIZE FACULTY W/O DOCATORATES	38	39	19	19	10	125	30%	31%	15%	15%	8%
A1. GRADUATE PROGRAM ATTRACTIVENESS	92	89	8	14	9	212	43%	42%	4%	7%	4%
A2. PROFICIENCY IN ENGLISH	92	52	4	17	46	211	44%	25%	2%	8%	22%
A3. PROFESSIONAL COMPETENCE	108	86	8	4	4	210	51%	41%	4%	2%	2%
A4. UTILIZE FACULTY W/O DOCTORATES	93	84	8	12	12	209	44%	40%	4%	6%	6%
CURRICULUM ISSUES											
1. COMPUTER USE	130	108	16	6	3	263	49%	41%	6%	2%	1%
2. MANUFACTURING & CONSTRUCTION	80	131	29	19	5	264	30%	50%	11%	7%	2%
3. BASIC SCIENCE REQUIREMENT	77	129	32	20	6	264	29%	49%	12%	8%	2%
4. MATHEMATICS REQUREMENT	121	124	9	4	5	263	46%	47%	3%	2%	2%
5. THE GLOBAL ECONOMY	65	112	48	24	14	263	25%	43%	18%	9%	5%
6. THE INDUSTRIAL ENVIRONMENT	90	119	29	15	11	264	34%	45%	11%	6%	4%
7. ENGINEERING SCIENCE CRITERIA	79	120	42	16	5	262	30%	46%	16%	6%	2%
8. BASIC EDUCATION REQUIREMENT	83	102	35	24	17	261	32%	39%	13%	9%	7%
9. ENGINEERING DESIGN CRITERIA	136	102	10	10	6	264	52%	39%	4%	4%	2%
10. LIBERAL ARTS & HUMANITIES	79	123	25	19	17	263	30%	47%	10%	7%	6%
11. INTERNATIONAL ACCREDITATION	42	51	101	28	40	262	16%	19%	39%	11%	15%
12. PROFESSIONAL-LEVEL ACCREDITATION	48	93	48	31	40	260	18%	36%	18%	12%	15%
13. ACADEMIC PROGRAM LENGTH											
I. ENCOURAGE 5-YEAR PROGRAM	44	48	16	54	95	257	17%	19%	6%	21%	37%
II. REDUCE TECHNICAL CONTENT	23	41	24	58	113	259	9%	16%	9%	22%	44%
III. REINSTITUTE DUAL LEVEL	46	49	41	35	85	256	18%	19%	16%	14%	33%
IV. PRESCRIBE 5-YEARS BY 1995	46	31	24	41	115	257	18%	12%	9%	16%	45%
14. REQUIRE STATISTICS	51	97	34	16	23	221	23%	44%	15%	7%	10%
15. HEALTH & SAFETY	33	74	56	33	19	215	15%	34%	26%	15%	9%
16. LANGUAGE ADMISSION REQUIREMENT	27	65	44	30	45	211	13%	31%	21%	14%	21%
17. REQUIRE ORIENTAL LANGUAGES	20	64	59	32	41	216	9%	30%	27%	15%	19%
18. D. ENG. AS PROFESSIONAL DEGREE	14	23	34	37	99	207	7%	11%	16%	18%	48%
B1. INTERNATIONAL ACCREDITATION	34	45	54	33	51	217	16%	21%	25%	15%	24%
B2. PROFESSIONAL-LEVEL ACCREDITATION	41	72	23	44	37	217	19%	33%	11%	20%	17%
B3. REQUIRE STATISTICS	51	83	10	40	34	218	23%	38%	5%	18%	16%
B4. HEALTH & SAFETY	60	89	13	32	24	218	28%	41%	6%	15%	11%
B5. LANGUAGE ADMISSION REQUIREMENT	31	48	20	54	67	220	14%	22%	9%	25%	30%
B6. MASTERY OF ENGLISH REQUIREMENT	80	69	16	27	29	221	36%	31%	7%	12%	13%
B7. REQUIRE ORIENTAL LANGUAGES	8	30	29	40	109	216	4%	14%	13%	19%	50%
B8. ENCOURAGE 5-YEAR PROGRAM	61	45	11	38	62	217	28%	21%	5%	18%	29%
B9. REINSTITUTE DUAL LEVEL ACCRED.	52	53	18	34	59	216	24%	25%	8%	16%	27%

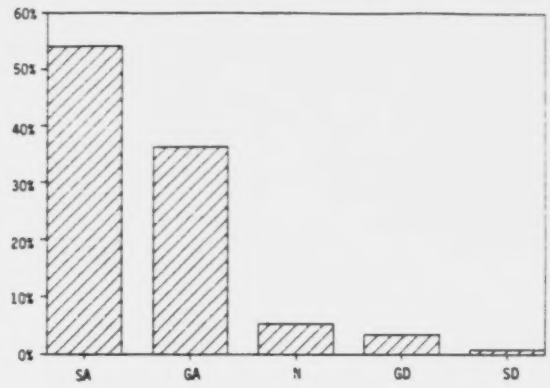
	Number of Votes Cast						% of Votes Cast				
BROAD ACADEMIC ISSUES											
1. LIMITING PROGRAMS	52	76	27	47	71	273	19%	28%	10%	17%	26%
2. MORATORIUM ON PhD PROGRAMS	68	77	19	47	61	272	25%	28%	7%	17%	22%
3. MORATORIUM ON NEW SCHOOLS	84	61	27	48	52	272	31%	22%	10%	18%	19%
4. FACULTY & LAB REQUIREMENTS	87	111	24	29	20	271	32%	41%	9%	11%	7%
5. ADMISSIONS REQUIREMENTS	105	93	17	32	25	272	39%	34%	6%	12%	9%
6. REGISTRATION FOR TEACHING	81	70	18	41	62	272	30%	26%	7%	15%	23%
7. ADVISORY COMMITTEES	89	113	25	21	24	272	33%	42%	9%	8%	9%
8. QUALITY GOALS	56	95	32	60	28	271	21%	35%	12%	22%	10%
9. UNIVERSITY ENVIRONMENT	94	112	28	16	20	270	35%	41%	10%	6%	7%
10. CONTINUING EDUCATION	64	110	39	33	25	271	24%	41%	14%	12%	9%
11. COMPETITIVENESS	176	76	13	4	2	271	65%	28%	5%	1%	1%
12. NATIONAL SCIENCE BOARD	161	70	32	2	0	265	61%	26%	12%	1%	0%
D1. LIMITING PROGRAMS	48	61	18	38	45	210	23%	29%	9%	18%	21%
D2. MORATORIUM ON PhD PROGRAMS	27	50	10	49	75	211	13%	24%	5%	23%	36%
D3. MORATORIUM ON NEW SCHOOLS	43	41	14	40	70	208	21%	20%	7%	19%	34%
D4. REGISTRATION FOR TEACHING (1st)	59	38	5	39	67	208	28%	18%	2%	19%	32%
D5. QUALITY GOALS	21	54	13	64	51	203	10%	27%	6%	32%	25%
D6. CONTINUING EDUCATION	37	98	22	25	23	205	18%	48%	11%	12%	11%
D7. MINORITIES & WOMEN	39	57	13	42	53	204	19%	28%	6%	21%	26%
D8. DR. OF ENG. AS 1st PROFESSIONAL DEGREE	24	47	20	30	81	202	12%	23%	10%	15%	40%
D9. REGISTRATION FOR TEACHING (NCEE)	51	24	8	36	89	208	25%	12%	4%	17%	43%
LABORATORY, COMPUTER, AND EDUCATIONAL TECHNOLOGY ISSUES											
ROLE OF TECHNOLOGY											
1. FOCUS ON TEACHING	172	50	3	1	1	227	76%	22%	1%	0%	0%
2. LABORATORY EXPERIENCE	167	58	0	1	1	227	74%	26%	0%	0%	0%
3. LIBRARY	137	79	9	1	0	226	61%	35%	4%	0%	0%
4. LIFE-LONG LEARNING	141	65	9	8	3	226	62%	29%	4%	4%	1%
RESOURSE ALLOCATIONS											
1. INDUSTRY FINANCIAL SUPPORT	157	64	3	2	0	226	69%	28%	1%	1%	0%
2. COMPUTER MAINTENANCE	142	63	12	3	2	222	64%	28%	5%	1%	1%
3. DONATED EQUIPMENT	118	86	13	7	1	225	52%	38%	6%	3%	0%
4. UTILIZE REGIONAL LABORATORIES	31	55	48	21	13	168	18%	33%	29%	13%	8%
5. TECH. STAFF TRAINED BY INDUSTRY	52	67	34	7	6	166	31%	40%	20%	4%	4%
ACCREDITATION CRITERIA											
1. LABORATORY REQUIRMENT	76	96	22	12	11	217	35%	44%	10%	6%	5%
2. COMPUTER REQUIREMENT	66	102	22	14	12	216	31%	47%	10%	6%	6%
3. "STRAWMAN" CRITERIA	31	82	50	30	23	216	14%	38%	23%	14%	11%
C1. SPECIFIC CRITERIA	78	77	5	30	24	214	36%	36%	2%	14%	11%

FACULTY RESOLUTIONS

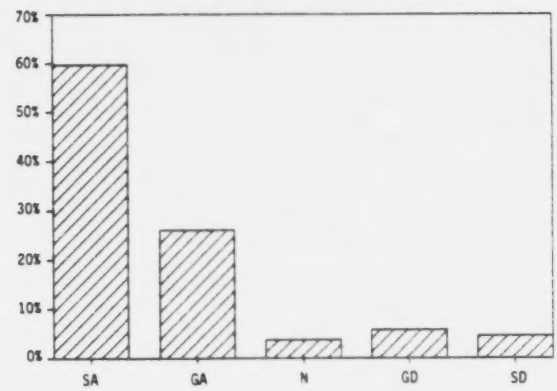
1. GRADUATE PROGRAM ATTRACTIVENESS



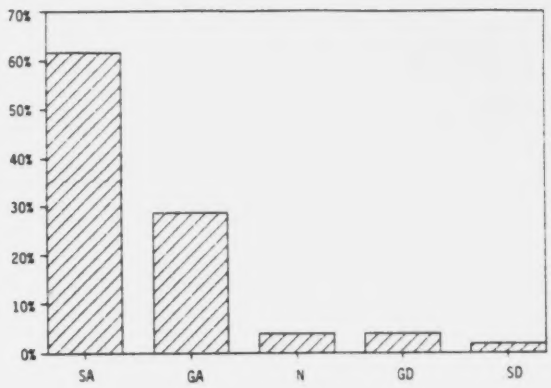
2. GRADUATE SUPPORT



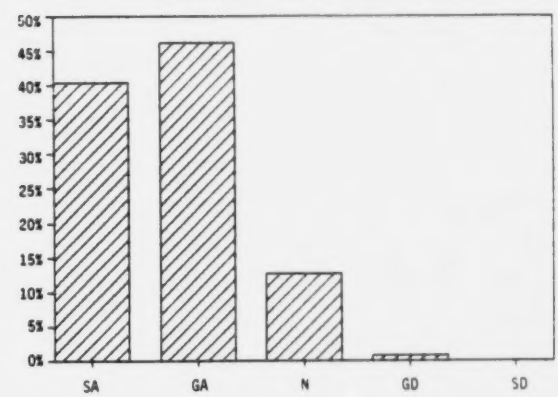
3. PROFICIENCY IN ENGLISH



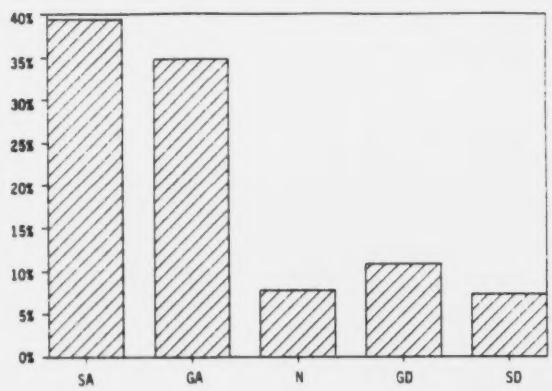
4. THE TEACHING FUNCTION



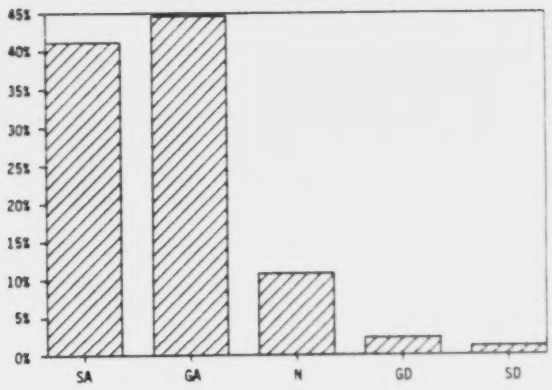
5. TEACHING WORKSHOPS



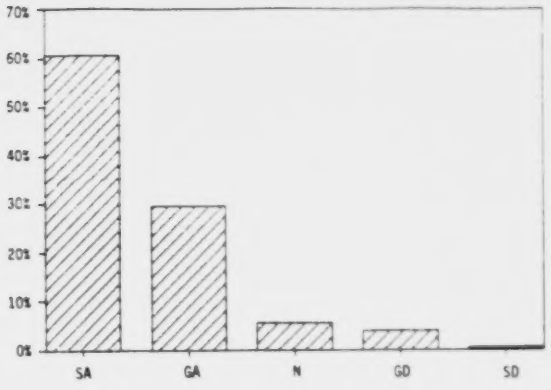
6. ENGINEERING PRACTICE



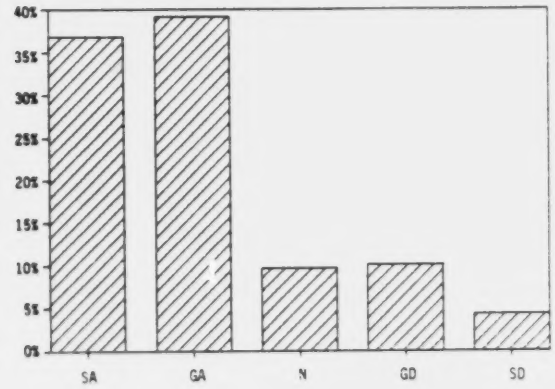
7. BALANCED DEPARTMENTS



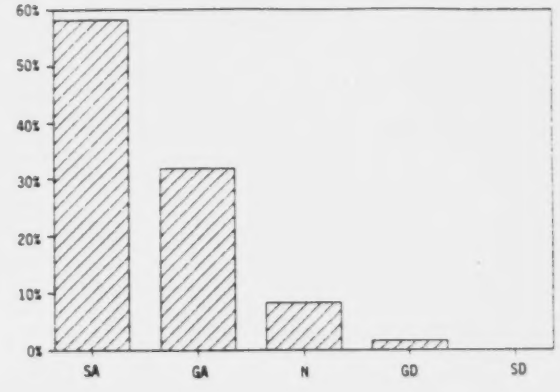
8. FACULTY CAREER ATTRACTIVENESS



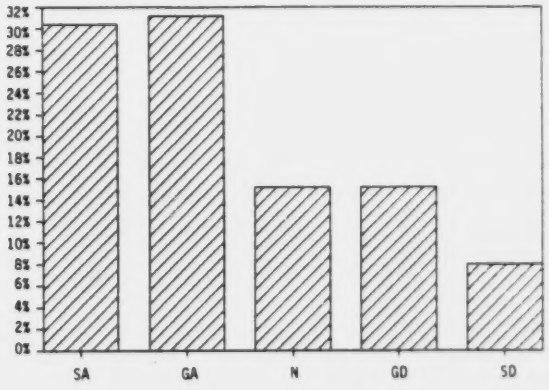
F9. PROFESSIONAL COMPETENCE



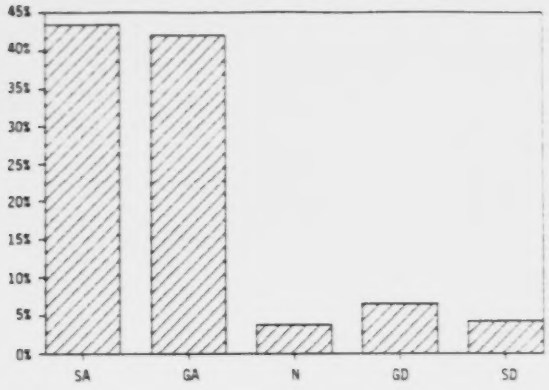
10. INTERACTION WITH INDUSTRY



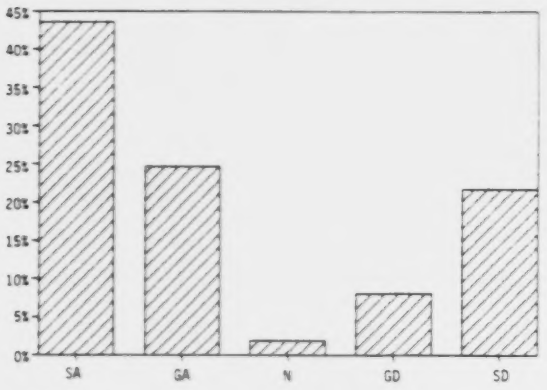
11. UTILIZE FACULTY W/O DOCTORATES



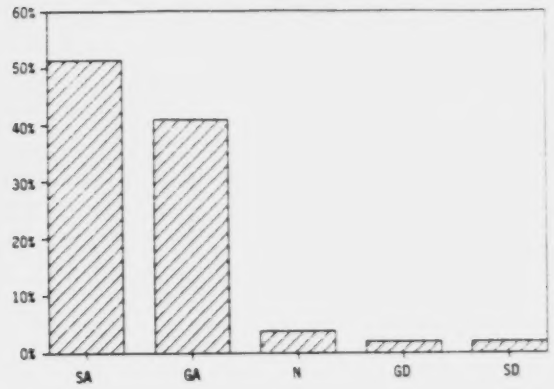
A1. GRADUATE PROGRAM ATTRACTIVENESS



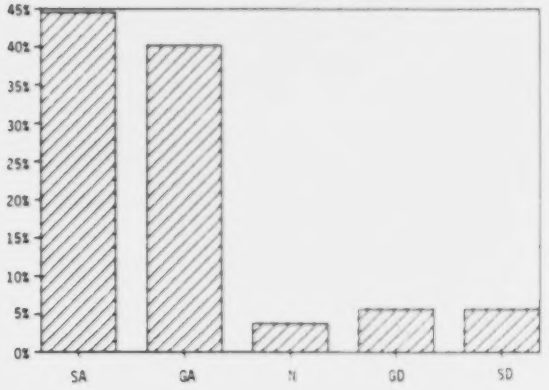
A2. PROFICIENCY IN ENGLISH



A3. PROFESSIONAL COMPETENCE

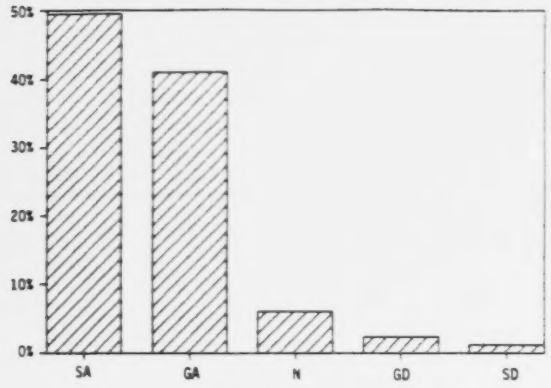


A4. UTILIZE FACULTY W/O DOCTORATES

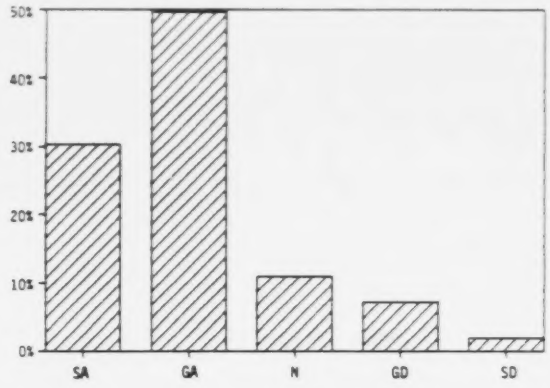


CURRICULUM ISSUES

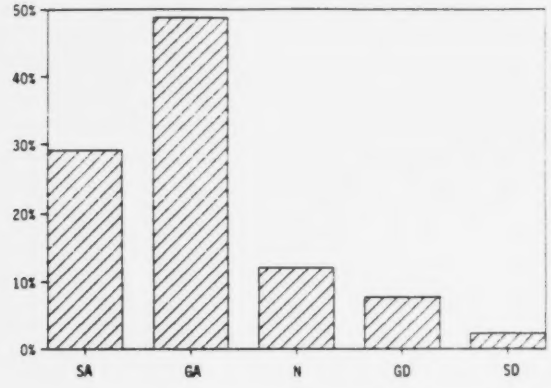
1. COMPUTER USE



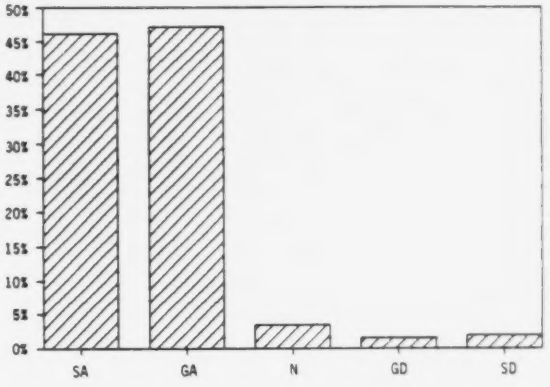
2. MANUFACTURING & CONSTRUCTION



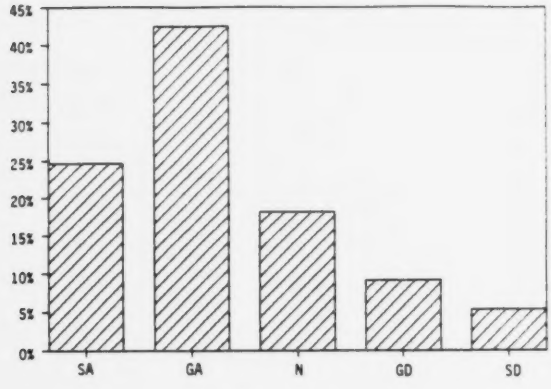
3. BASIC SCIENCE REQUIREMENT



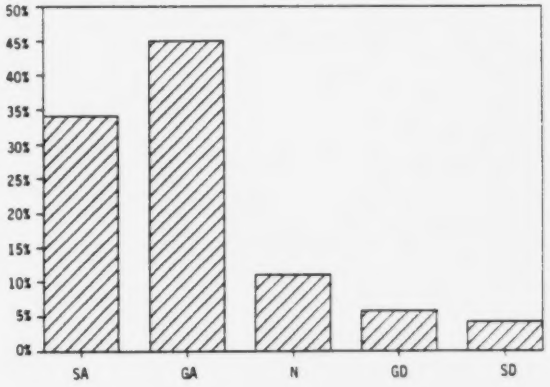
4. MATHEMATICS REQUIREMENT



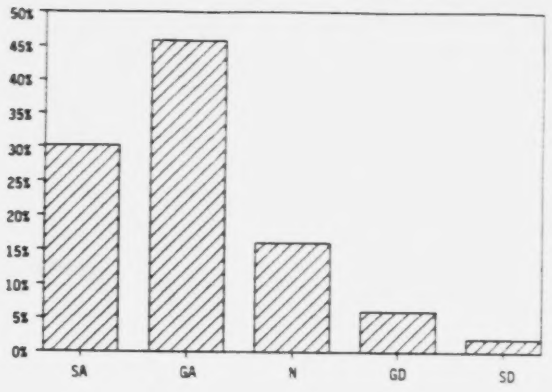
5. THE GLOBAL ECONOMY



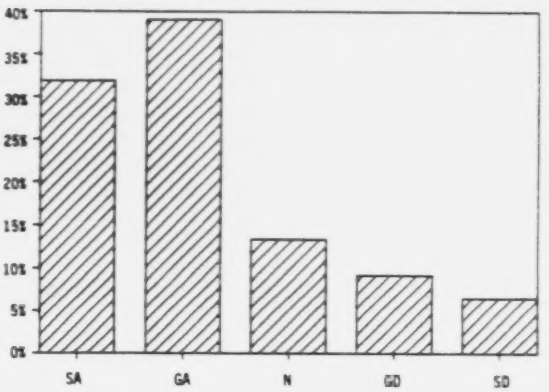
6. THE INDUSTRIAL ENVIRONMENT



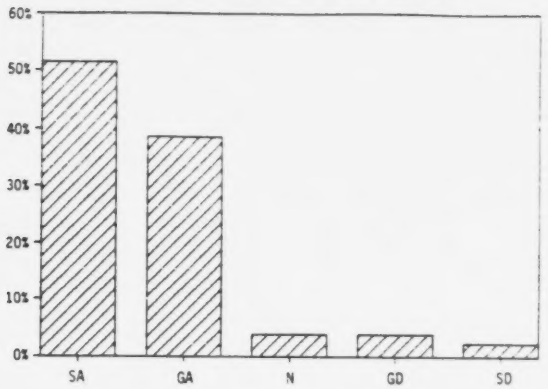
7. ENGINEERING SCIENCE CRITERIA



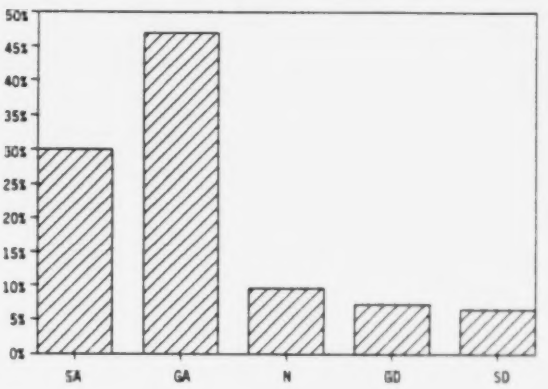
8. BASIC EDUCATION REQUIREMENT



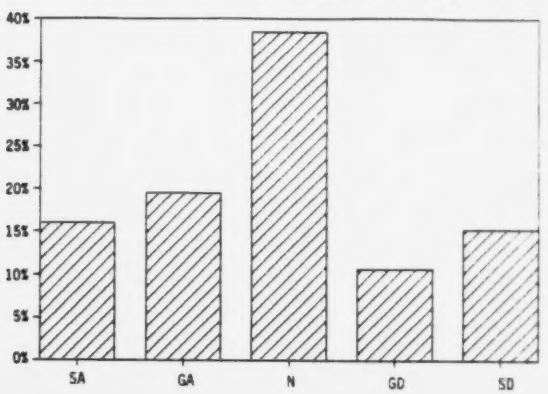
9. ENGINEERING DESIGN CRITERIA



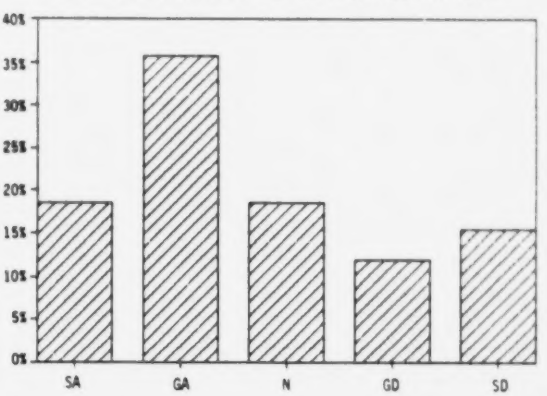
10. LIBERAL ARTS & HUMANITIES



11. INTERNATIONAL ACCREDITATION

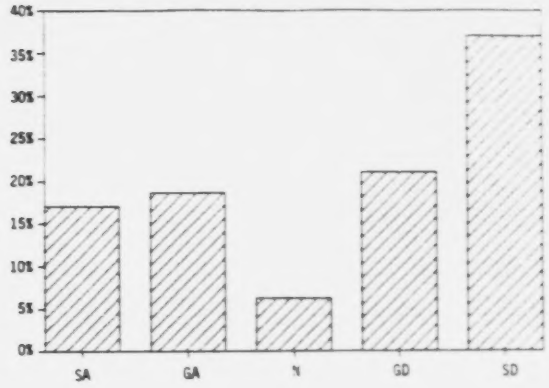


12. PROFESSIONAL-LEVEL ACCREDITATION

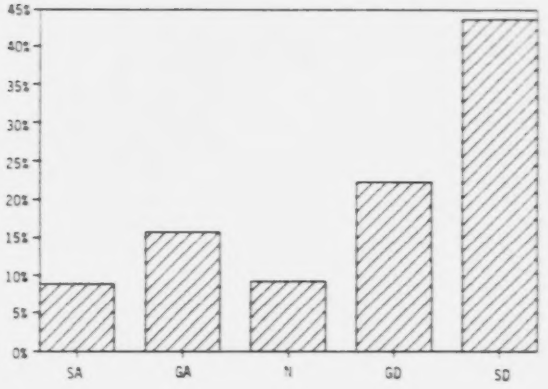


13. ACADEMIC PROGRAM LENGTH

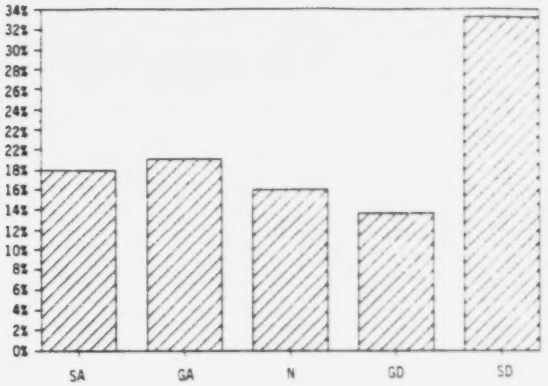
13. I. ENCOURAGE 5-YEAR PROGRAM



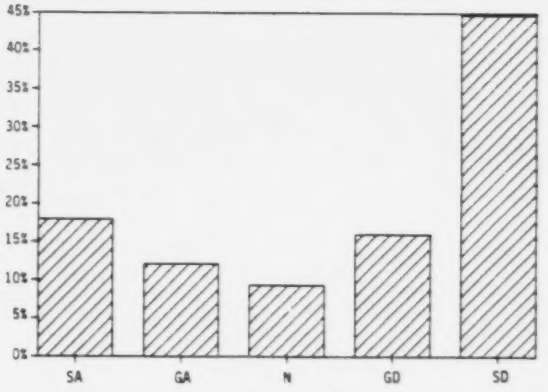
13. II. REDUCE TECHNICAL CONTENT



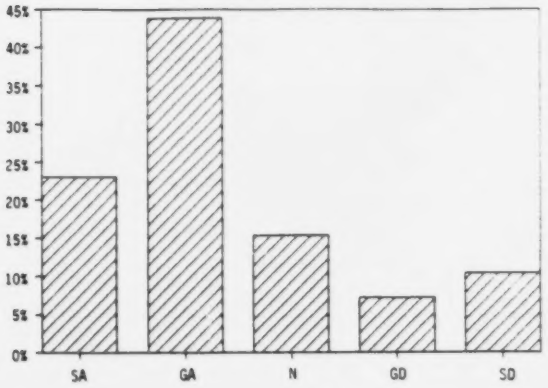
13. III. REINSTITUTE DUAL LEVEL



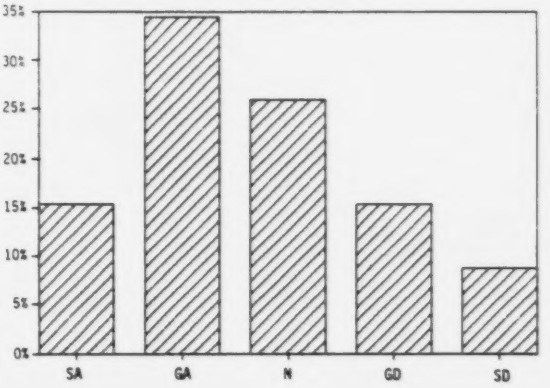
13. IV. PRESCRIBE 5-YEARS BY 1995



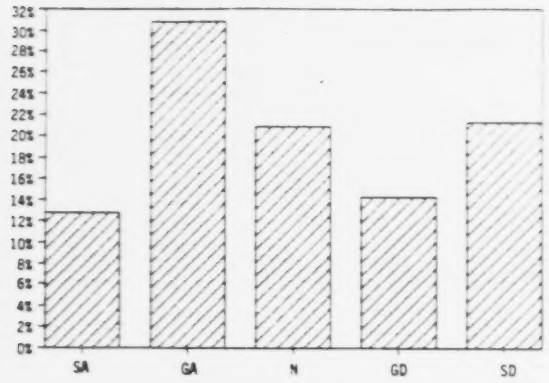
14. REQUIRE STATISTICS



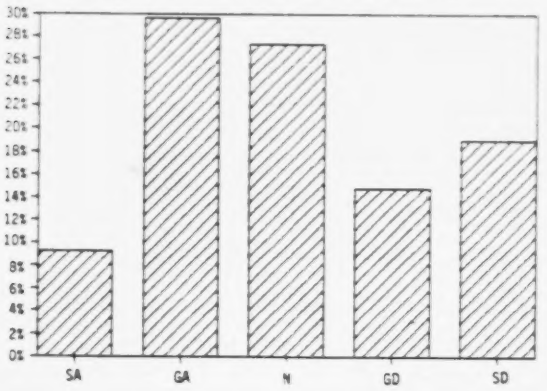
15. HEALTH & SAFETY



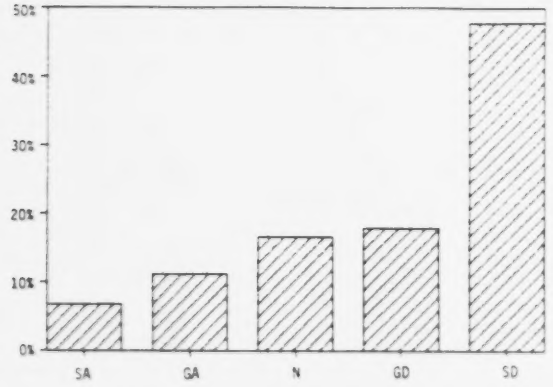
16. LANGUAGE ADMISSION REQUIREMENT



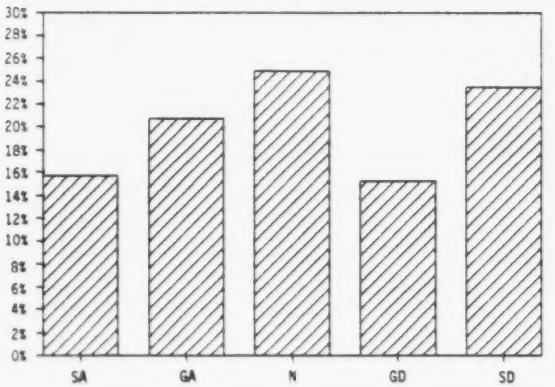
17. REQUIRE ORIENTAL LANGUAGES



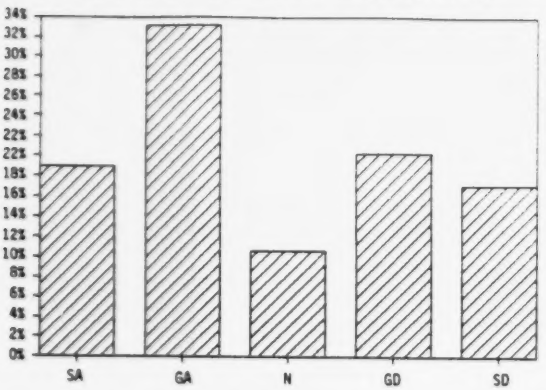
18. DR. ENG. AS PROFESSIONAL DEGREE



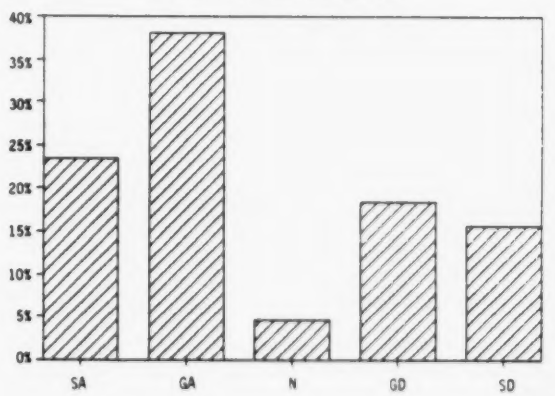
B1. INTERNATIONAL ACCREDITATION



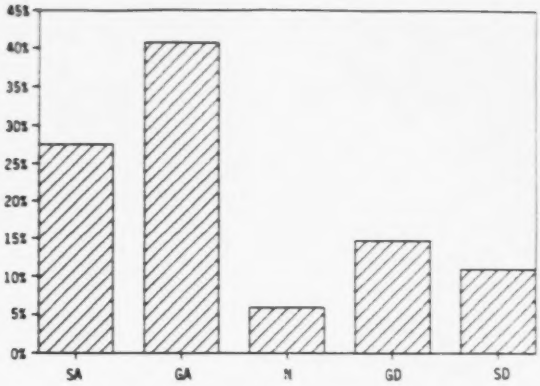
B2. PROFESSIONAL-LEVEL ACCREDITATION



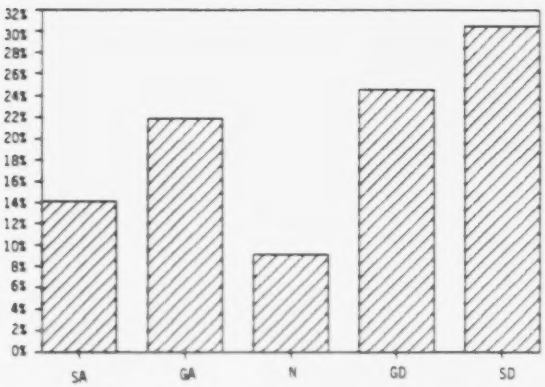
B3. REQUIRE STATISTICS



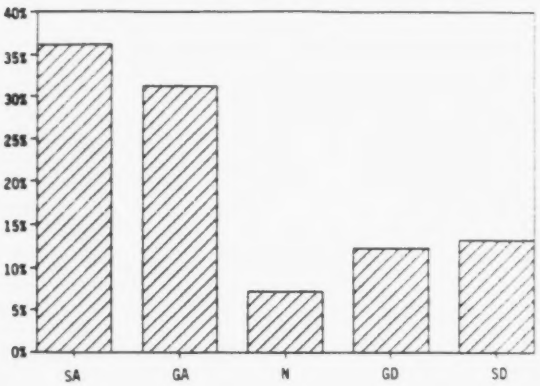
B4. HEALTH & SAFETY



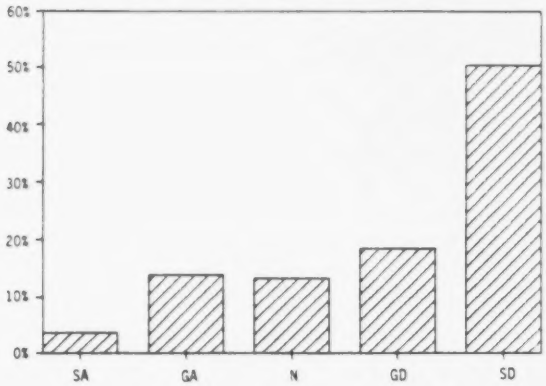
B5. LANGUAGE ADMISSION REQUIREMENT



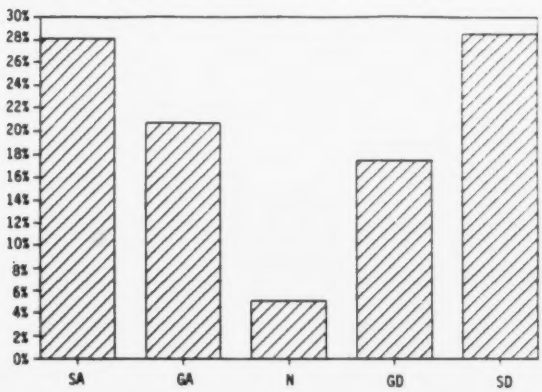
B6. MASTERY OF ENGLISH REQUIREMENT



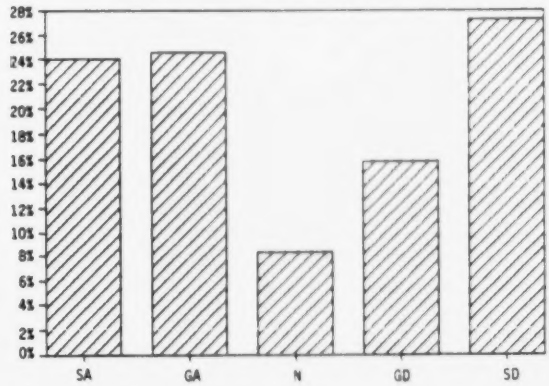
B7. REQUIRE ORIENTAL LANGUAGES



B8. ENCOURAGE 5-YEAR PROGRAM

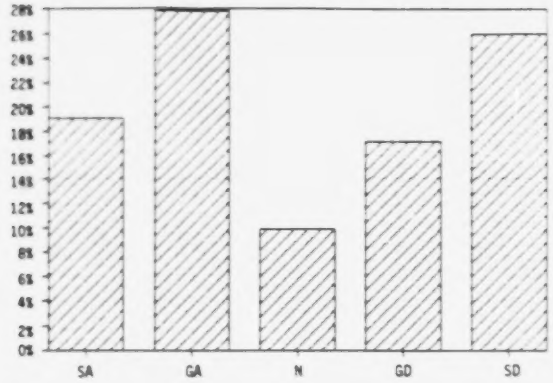


B9. REINSTITUTE DUAL LEVEL ACCRED.

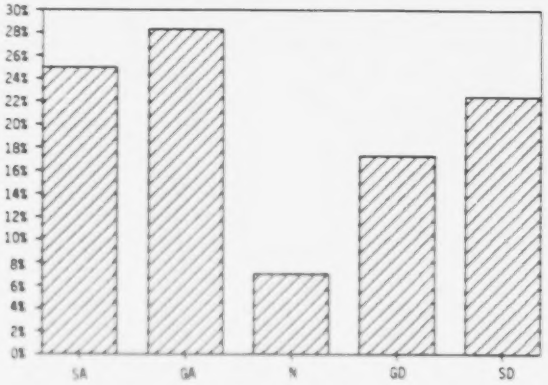


BROAD ACADEMIC ISSUES

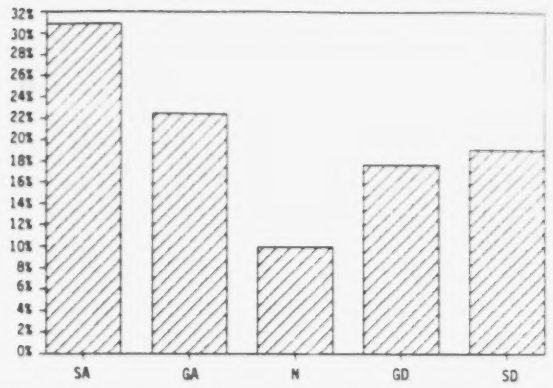
1. LIMITING PROGRAMS



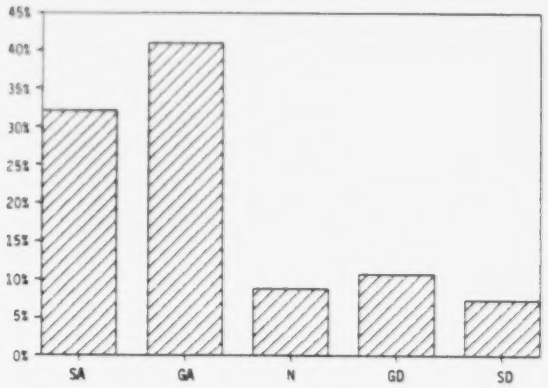
2. MORATORIUM ON PhD PROGRAMS



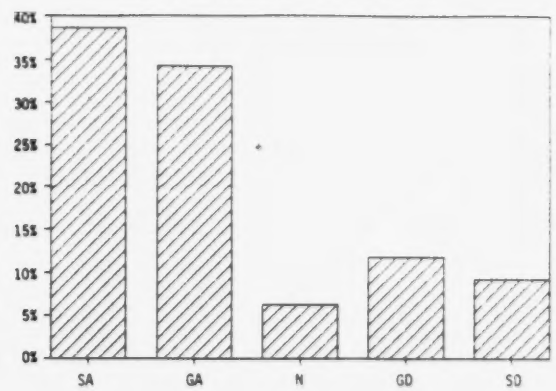
3. MORATORIUM ON NEW SCHOOLS



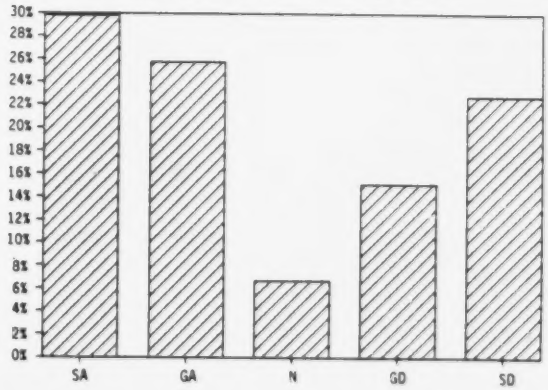
4. FACULTY & LAB REQUIREMENTS



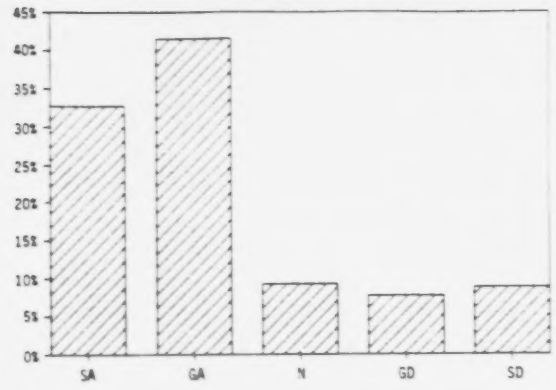
5.ADMISSIONS REQUIREMENTS



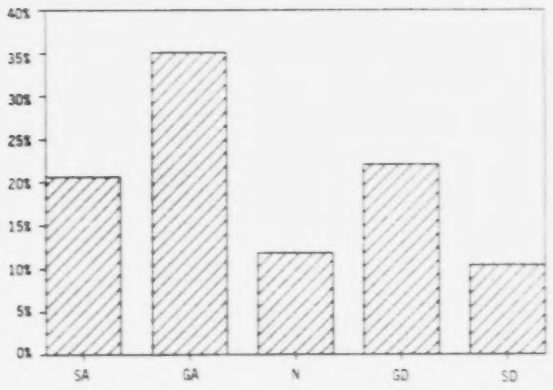
6. REGISTRATION FOR TEACHING



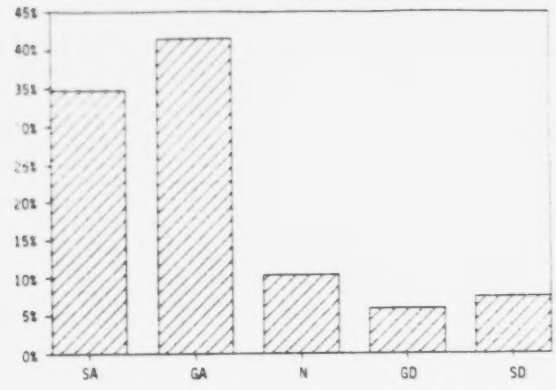
7. ADVISORY COMMITTEES



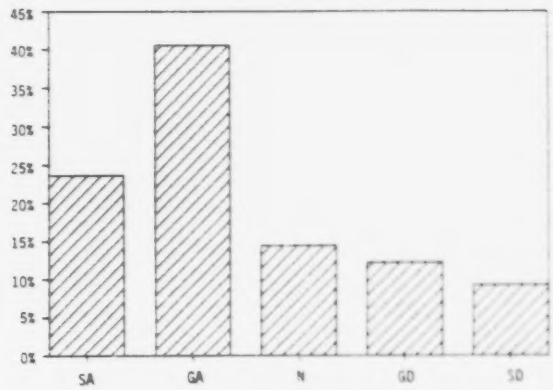
8. QUALITY GOALS



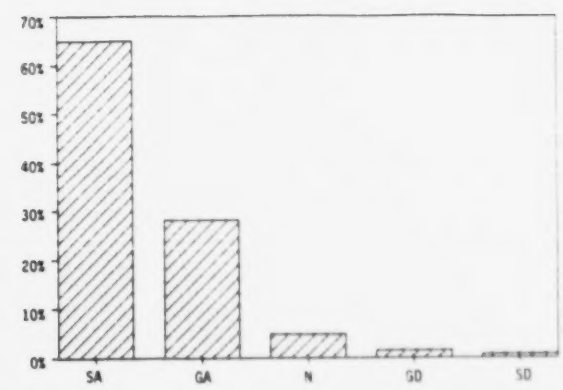
9. UNIVERSITY ENVIRONMENT



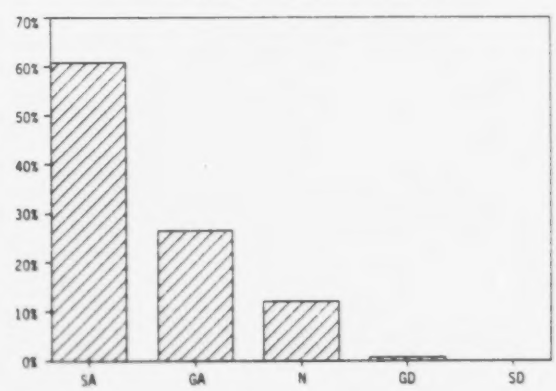
10 CONTINUING EDUCATION



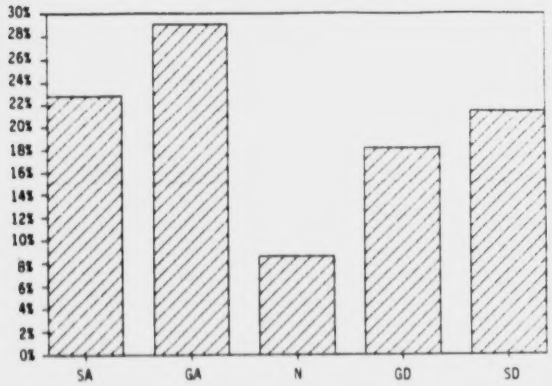
11. COMPETITIVENESS



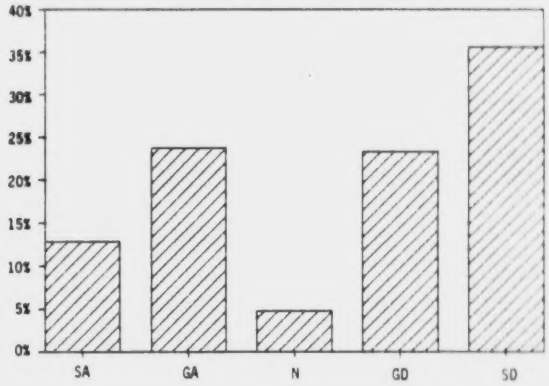
12. NATIONAL SCIENCE BOARD



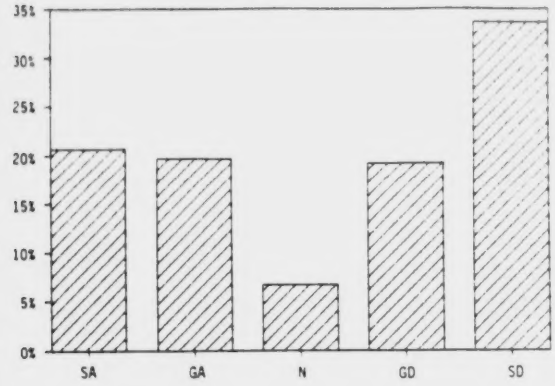
D1. LIMITING PROGRAMS



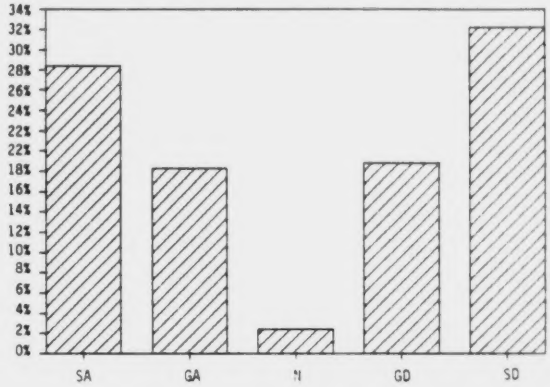
D2. MORATORIUM ON PhD PROGRAMS



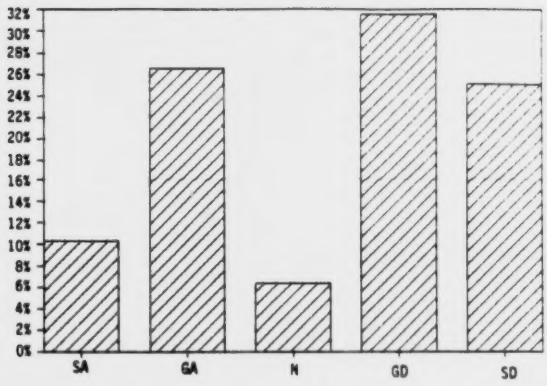
D3. MORATORIUM ON NEW SCHOOLS



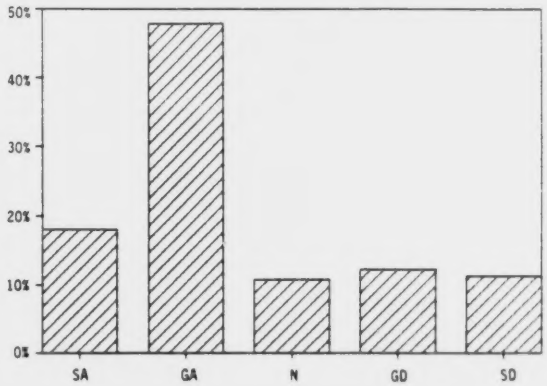
D4. REGISTRATION FOR TEACHING (1st)



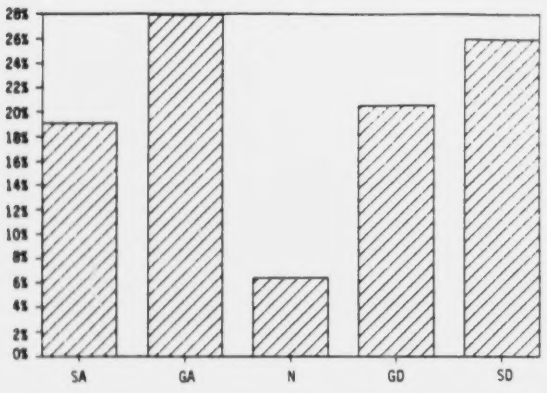
D5. QUALITY GOALS



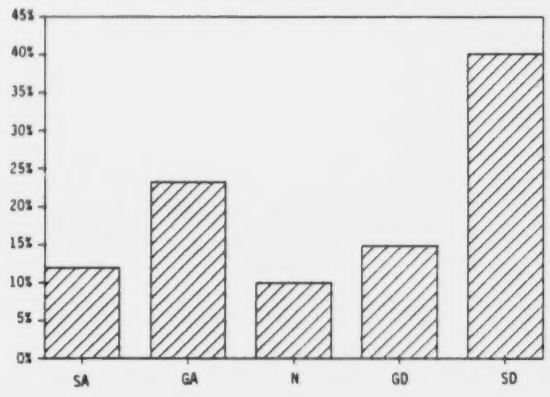
D6. CONTINUING EDUCATION



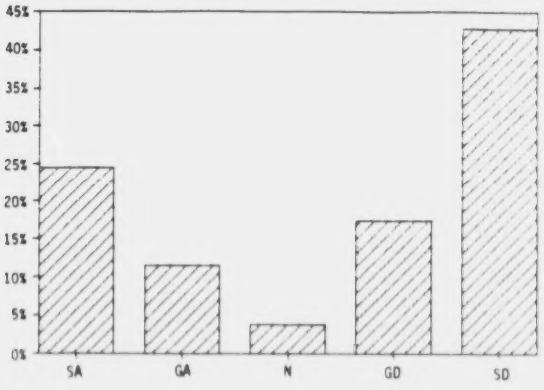
D7. MINORITIES & WOMEN



D8. DR. OF ENG. AS PROFESSIONAL DEGREE



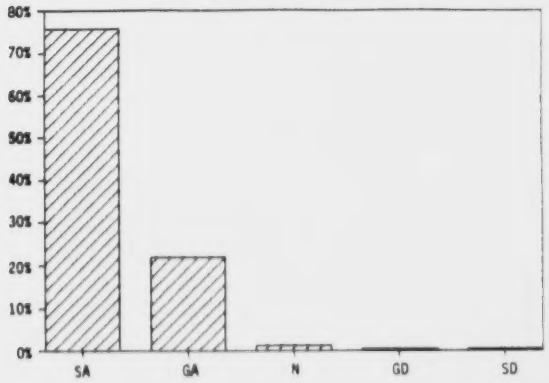
D9. REGISTRATION FOR TEACHING (NCEE)



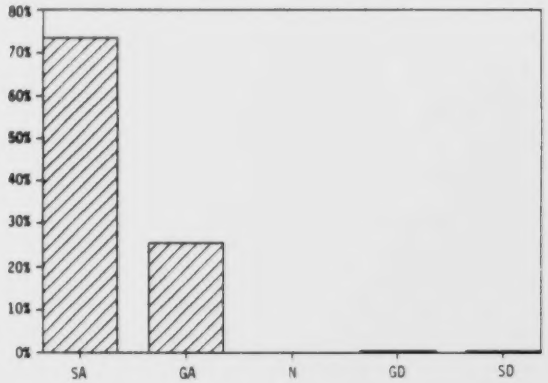
LABORATORY, COMPUTER, AND EDUCATIONAL TECHNOLOGY ISSUES

ROLE OF TECHNOLOGY

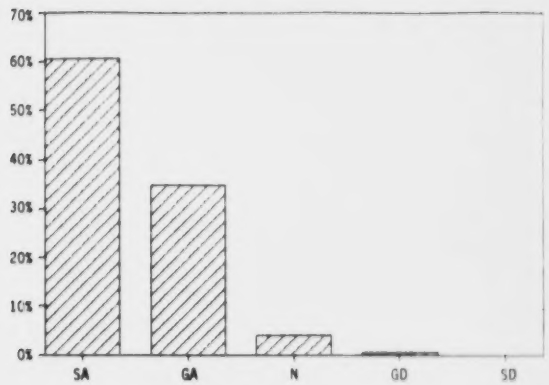
1. FOCUS ON TEACHING



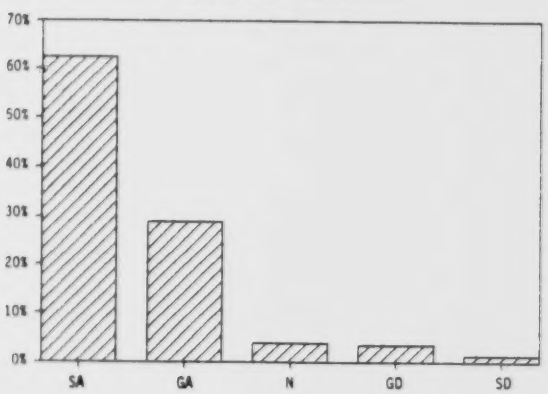
2. LABORATORY EXPERIENCE



3. LIBRARY

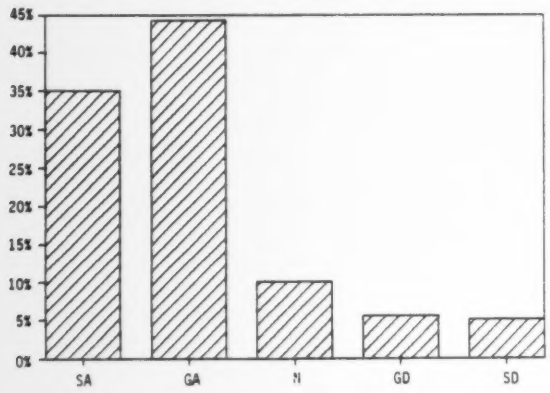


4. LIFE-LONG LEARNING

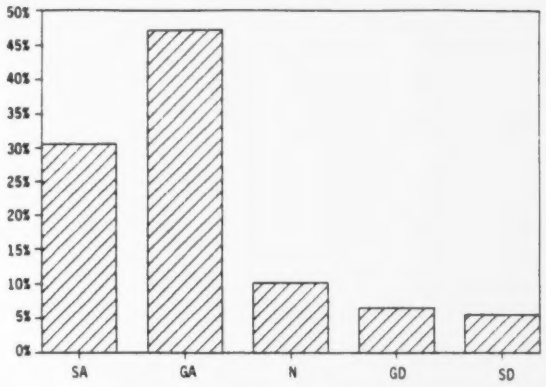


ACCREDITATION CRITERIA

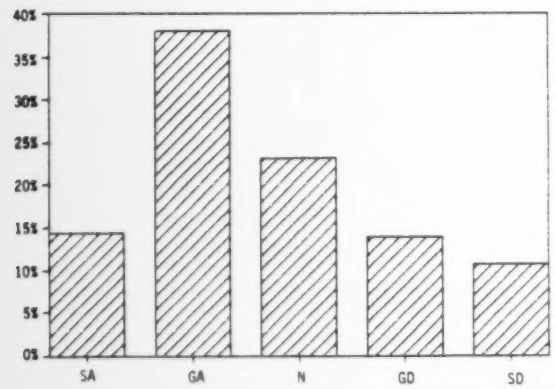
1. LABORATORY REQUIREMENT



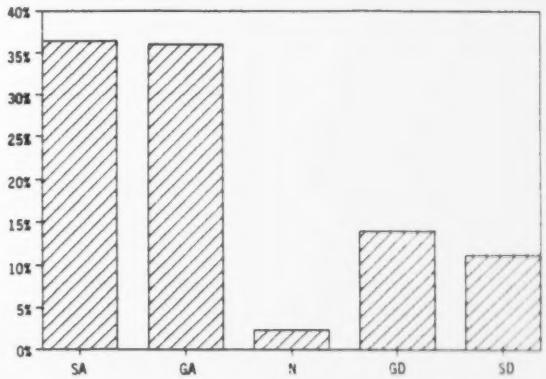
2. COMPUTER REQUIREMENT



3. "STRAWMAN" CRITERIA

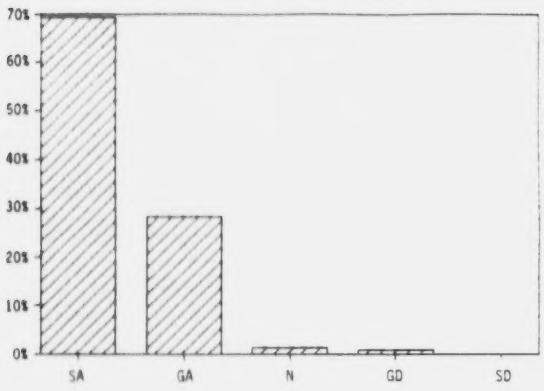


C1. SPECIFIC CRITERIA

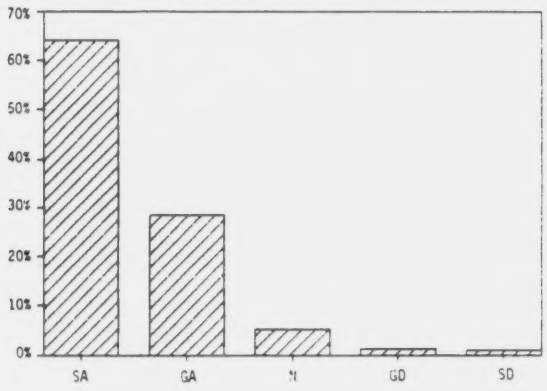


RESOURCE ALLOCATIONS

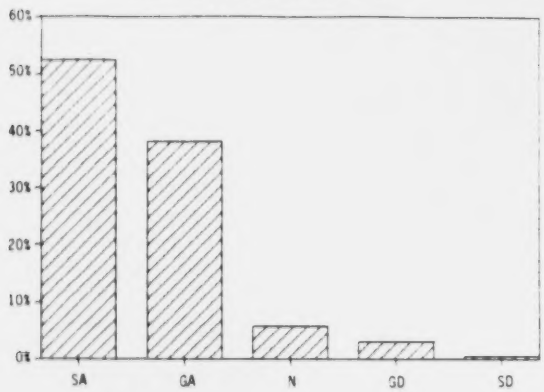
1. INDUSTRY FINANCIAL SUPPORT



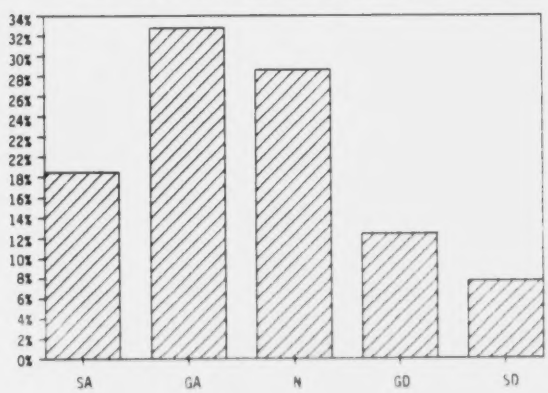
2. COMPUTER MAINTENANCE



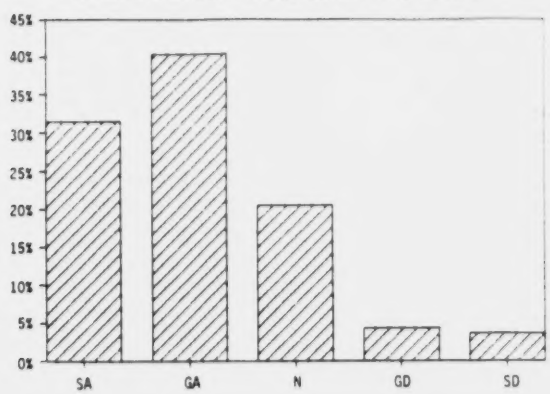
3. DONATED EQUIPMENT



4. UTILIZE REGIONAL LABORATORIES



5. TECH. STAFF TRAINED BY INDUSTRY



NC2E

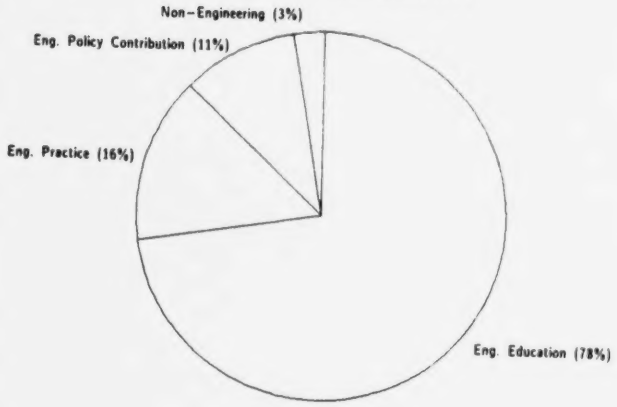
APPENDIX D

Participant Profile Analysis

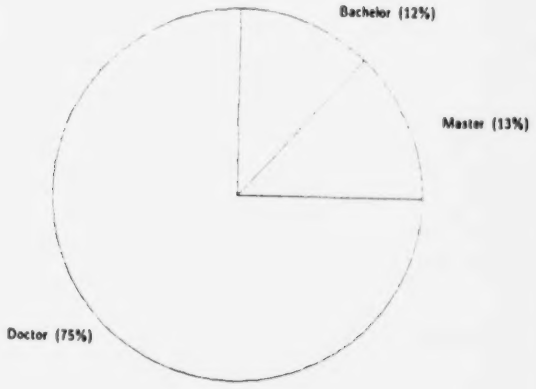
TOTAL NUMBER OF PROFILES	302	
1. AREA OF MAJOR ACTIVITY		
ENGINEERING EDUCATION	236	78%
ENGINEERING PRACTICE	47	16%
ENGINEERING POLICY CONTRIBUTION	33	11%
NON-ENGINEERING	9	3%
2. AGE:		
UNDER 40	13	4%
40-60	219	73%
OVER 60	61	20%
3. DEGREES HELD		
ENGINEERING		
BACHELOR	31	10%
MASTER	21	7%
DOCTOR	212	70%
NON-ENGINEERING		
BACHELOR	6	2%
MASTER	21	7%
DOCTOR	24	8%
4. TYPE OF EMPLOYER		
EDUCATIONAL INSTITUTION	228	75%
MAJOR DIVERSIFIED COMPANY	11	4%
BASICALLY TECHNICAL COMPANY	14	5%
CONSULTING FIRM	13	4%
GOVERNMENT	22	7%
ENGINEERING SOCIETY (STAFF)	19	6%
SELF EMPLOYED	3	1%
RETIRED	7	2%
5. MAJOR FUNCTION		
MANAGER	156	52%
ADMINISTRATION	171	57%
ENGINEERING DESIGN	18	6%
RESEARCH/DEVELOPMENT	27	9%
PRODUCTION/CONSTRUCTION	5	2%
TEACHING	103	34%
CONSULTING	25	8%
6. a. PARTICIPANTS WHO SUPERVISE ENGINEERS	212	70%
b. PARTICIPANTS WHO SUPERVISE NON-ENGINEERS	187	62%
7. PARTICIPANTS WITH ENGINEERS IN THEIR ORG. UNIT	214	71%
8. TECHNICAL SPECIALTY:		
AEROSPACE	13	4%
BIOENGINEERING	6	2%
CHEMICAL	29	10%
CIVIL	64	21%
ELECTRICAL	69	23%
INDUSTRIAL	16	5%
MATERIALS	16	5%
MECHANICAL	86	28%
MINING	3	1%
OTHER ENGINEERING	35	12%
SCIENCE	11	4%
NON-TECHNICAL	11	4%
9. OTHER CHARACTERISTICS:		
LICENSED PROFESSIONAL ENGINEER	191	63%
OFFICER OF ENGINEERING SOCIETY	118	39%
MEMBER PROFESSIONAL/TECHNICAL SOCIETY	257	85%
MEMBER SOCIETY EDUCATION COMMITTEE	112	37%
AUTHOR OF REFEREED ARTICLE	191	63%
AUTHOR OF OTHER TYPE PUBLICATION	192	64%
10. ATTENDING AS DELGATE OF AN ENGINEERING SOCIETY	42	14%

NC2E – PARTICIPANT PROFILE

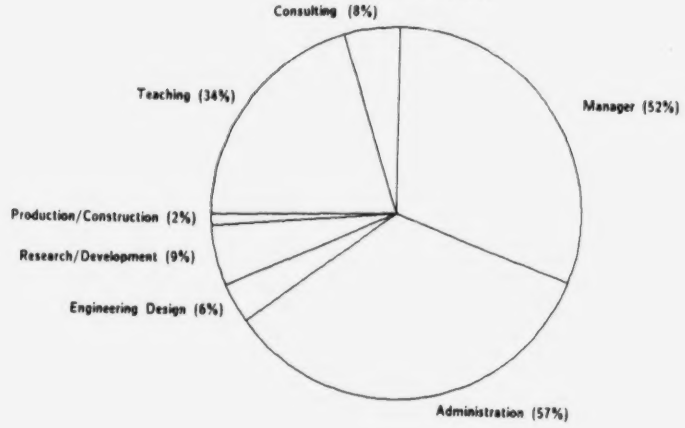
AREA OF MAJOR ACTIVITY



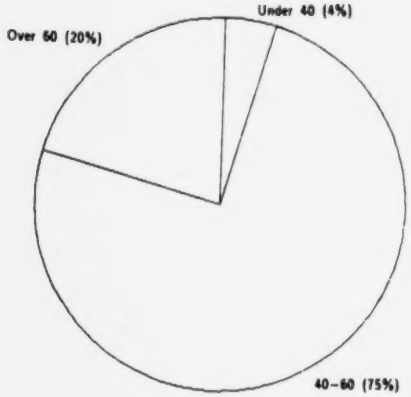
DEGREES HELD



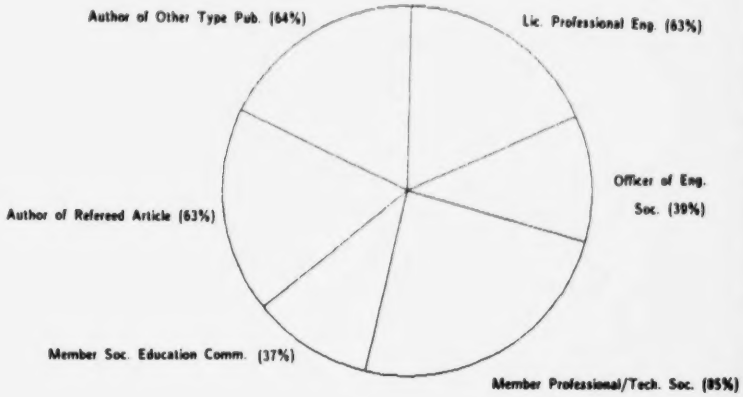
MAJOR FUNCTION



AGE



OTHER CHARACTERISTICS


Author of Other Type Pub. (64%)
Lic. Professional Eng. (63%)
Officer of Eng. Soc. (39%)
Author of Refereed Article (63%)
Member Soc. Education Comm. (37%)
Member Professional/Tech. Soc. (85%)

NCQE

APPENDIX E

Cross–Tabulations

NC2E - NATIONAL CONGRESS ON ENGINEERING EDUCATION

RESOLUTION STATISTICS, BROKEN DOWN BY "5. MAJOR FUNCTION" FROM PARTICIPANT PROFILE

	ADMINISTRATION					ENG. DESIGN & PROD.					RESEARCH/DEVELOPMENT					TEACHING				
FACULTY RESOLUTIONS	SA	GA	N	GD	SD	SA	GA	N	GD	SD	SA	GA	N	GD	SD	SA	GA	N	GD	SD
1. GRADUATE PROGRAM ATTRACTIVENESS	22%	44%	18%	10%	6%	19%	23%	19%	19%	19%	21%	67%	4%	8%	0%	31%	40%	13%	12%	3%
2. GRADUATE SUPPORT	57%	34%	6%	3%	0%	19%	21%	21%	19%	19%	46%	42%	8%	4%	0%	54%	40%	1%	2%	2%
3. PROFICIENCY IN ENGLISH	62%	22%	4%	8%	3%	21%	21%	19%	19%	19%	46%	38%	4%	8%	4%	52%	32%	2%	4%	10%
4. THE TEACHING FUNCTION	64%	26%	3%	4%	2%	19%	23%	19%	19%	19%	71%	21%	4%	0%	4%	65%	24%	2%	5%	3%
5. TEACHING WORKSHOPS	42%	44%	13%	1%	0%	20%	20%	21%	19%	19%	29%	67%	4%	0%	0%	37%	49%	11%	2%	0%
6. ENGINEERING PRACTICE	38%	35%	8%	10%	8%	21%	21%	19%	19%	19%	33%	33%	17%	13%	4%	33%	37%	12%	10%	9%
7. BALANCED DEPARTMENTS	38%	46%	12%	3%	1%	19%	23%	19%	19%	19%	54%	38%	8%	0%	0%	44%	44%	8%	2%	2%
8. FACULTY CAREER ATTRACTIVENESS	60%	30%	6%	4%	0%	19%	21%	20%	20%	19%	74%	17%	9%	0%	0%	66%	30%	2%	2%	0%
9. PROFESSIONAL COMPETENCE	36%	36%	10%	14%	4%	20%	22%	19%	19%	19%	33%	46%	4%	13%	4%	28%	46%	10%	9%	8%
10. INTERACTION WITH INDUSTRY	61%	28%	9%	2%	0%	20%	20%	21%	19%	19%	58%	33%	4%	4%	0%	56%	36%	6%	2%	0%
11. UTILIZE FACULTY W/O DOCTORATES	23%	33%	17%	20%	8%	20%	21%	20%	20%	20%	14%	36%	14%	29%	7%	34%	27%	16%	20%	2%
A1. GRADUATE PROGRAM ATTRACTIVENESS	39%	46%	6%	5%	4%	22%	20%	20%	20%	20%	44%	50%	0%	6%	0%	39%	48%	3%	6%	4%
A2. PROFICIENCY IN ENGLISH	40%	24%	1%	11%	25%	21%	21%	20%	20%	20%	28%	11%	6%	22%	33%	41%	22%	1%	8%	28%
A3. PROFESSIONAL COMPETENCE	52%	41%	4%	3%	1%	20%	22%	20%	20%	20%	33%	56%	0%	0%	11%	41%	48%	5%	3%	3%
A4. UTILIZE FACULTY W/O DOCTORATES	41%	44%	4%	4%	6%	21%	21%	20%	20%	20%	28%	56%	0%	6%	11%	40%	43%	3%	8%	7%
CURRICULUM ISSUES																				
1. COMPUTER USE	51%	41%	5%	3%	1%	21%	21%	19%	19%	19%	33%	46%	17%	4%	0%	49%	39%	8%	3%	1%
2. MANUFACTURING & CONSTRUCTION	25%	53%	9%	9%	3%	21%	20%	20%	19%	19%	38%	58%	4%	0%	0%	23%	51%	17%	7%	1%
3. BASIC SCIENCE REQUIREMENT	33%	49%	11%	4%	2%	19%	23%	19%	19%	19%	21%	67%	0%	13%	0%	29%	51%	11%	9%	1%
4. MATHEMATICS REQUIREMENT	50%	44%	3%	1%	1%	20%	22%	19%	19%	19%	42%	58%	0%	0%	0%	39%	55%	3%	1%	2%
5. THE GLOBAL ECONOMY	24%	42%	20%	7%	6%	20%	21%	20%	19%	19%	25%	50%	8%	13%	4%	22%	43%	20%	11%	4%
6. THE INDUSTRIAL ENVIRONMENT	28%	49%	11%	5%	5%	21%	20%	20%	19%	19%	42%	50%	0%	4%	4%	29%	51%	10%	5%	5%
7. ENGINEERING SCIENCE CRITERIA	30%	50%	15%	3%	1%	19%	21%	20%	20%	19%	22%	57%	17%	0%	4%	30%	43%	16%	10%	1%
8. BASIC EDUCATION REQUIREMENT	29%	42%	11%	10%	8%	21%	20%	20%	19%	19%	38%	29%	17%	17%	0%	27%	39%	21%	7%	7%
9. ENGINEERING DESIGN CRITERIA	51%	37%	4%	5%	3%	20%	22%	19%	19%	19%	54%	33%	4%	4%	4%	47%	44%	3%	3%	2%
10. LIBERAL ARTS & HUMANITIES	33%	46%	9%	4%	8%	19%	21%	21%	19%	19%	33%	42%	13%	13%	0%	23%	49%	9%	12%	7%
11. INTERNATIONAL ACCREDITATION	22%	14%	37%	11%	16%	19%	19%	23%	19%	19%	21%	21%	42%	4%	13%	11%	18%	42%	10%	19%
12. PROFESSIONAL-LEVEL ACCREDITATION	19%	35%	21%	12%	13%	19%	22%	20%	19%	19%	13%	38%	21%	13%	17%	18%	39%	16%	11%	15%
13. ACADEMIC PROGRAM LENGTH:																				
I. ENCOURAGE 5-YEAR PROGRAM	19%	20%	4%	22%	35%	20%	19%	21%	19%	20%	9%	26%	13%	22%	30%	13%	17%	7%	20%	43%
II. REDUCE TECHNICAL CONTENT	10%	12%	10%	23%	45%	19%	19%	21%	20%	20%	4%	26%	13%	17%	39%	5%	15%	5%	23%	51%
III. REINSTITUTE DUAL LEVEL	16%	20%	18%	16%	30%	21%	19%	19%	20%	20%	26%	26%	9%	4%	35%	16%	14%	10%	14%	46%
IV. PRESCRIBE 5-YEARS BY 1995	20%	13%	8%	16%	42%	20%	19%	21%	19%	20%	9%	13%	4%	35%	39%	11%	12%	9%	13%	55%

	Administration					Eng. Design & Prod.					Research/Devel.					Teaching				
14. REQUIRE STATISTICS	23%	42%	17%	5%	13%	19%	22%	20%	19%	19%	29%	43%	14%	10%	5%	20%	37%	13%	13%	16%
15. HEALTH AND SAFETY	17%	33%	26%	13%	10%	19%	22%	20%	19%	19%	27%	32%	23%	14%	5%	14%	29%	27%	15%	15%
16. LANGUAGE ADMISSION REQUIREMENT	9%	32%	20%	16%	22%	19%	22%	20%	19%	19%	14%	29%	24%	19%	14%	17%	22%	20%	13%	28%
17. REQUIRE ORIENTAL LANGUAGES	5%	30%	33%	14%	18%	19%	20%	22%	19%	19%	19%	24%	19%	24%	14%	6%	33%	23%	13%	26%
18. D. ENG. AS PROFESSIONAL DEGREE	4%	12%	19%	20%	46%	20%	19%	22%	19%	19%	10%	20%	10%	5%	55%	8%	8%	12%	16%	57%
B1. INTERNATIONAL ACCREDITATION	20%	18%	25%	14%	23%	20%	20%	21%	21%	20%	20%	40%	20%	5%	15%	15%	20%	23%	16%	26%
B2. PROFESSIONAL-LEVEL ACCREDITATION	19%	35%	11%	22%	13%	21%	21%	20%	20%	20%	15%	50%	15%	5%	15%	20%	36%	8%	19%	18%
B3. REQUIRE STATISTICS	23%	37%	3%	19%	18%	20%	22%	20%	20%	20%	25%	30%	5%	30%	10%	16%	36%	5%	21%	21%
B4. HEALTH & SAFETY	25%	42%	4%	15%	14%	21%	21%	20%	20%	20%	35%	40%	5%	15%	5%	24%	43%	8%	16%	10%
B5. LANGUAGE ADMISSION REQUIRMENT	14%	21%	8%	22%	36%	20%	22%	20%	20%	20%	10%	35%	10%	20%	25%	15%	24%	5%	33%	23%
B6. MASTERY OF ENGLISH REQUIRMENT	33%	30%	7%	15%	15%	20%	22%	20%	20%	20%	45%	25%	10%	10%	10%	35%	29%	7%	17%	11%
B7. REQUIRE ORIENTAL LANGUAGES	3%	12%	14%	22%	49%	20%	20%	22%	20%	20%	0%	21%	21%	11%	47%	4%	13%	13%	15%	56%
B8. ENCOURAGE 5-YEAR PROGRAM	26%	21%	6%	20%	28%	21%	21%	20%	20%	20%	42%	11%	0%	21%	26%	23%	15%	1%	21%	40%
B9. REINSTITUTE DUAL-LEVEL ACCRED.	24%	23%	6%	21%	26%	22%	20%	20%	20%	20%	32%	21%	11%	5%	32%	21%	23%	6%	17%	32%
BROAD ACADEMIC ISSUES																				
1. LIMITING PROGRAMS	21%	30%	8%	16%	25%	19%	20%	21%	20%	19%	12%	28%	16%	20%	24%	13%	27%	13%	13%	33%
2. MORATORIUM ON PhD PROGRAMS	27%	27%	5%	18%	23%	19%	20%	21%	20%	19%	12%	24%	8%	20%	36%	20%	29%	7%	21%	23%
3. MORATORIUM ON NEW SCHOOLS	36%	21%	8%	12%	23%	19%	21%	20%	20%	19%	32%	12%	16%	16%	24%	19%	22%	14%	26%	19%
4. FACULTY & LAB REQUIREMENTS	32%	36%	12%	11%	9%	20%	22%	19%	19%	19%	28%	64%	4%	4%	0%	32%	44%	2%	11%	10%
5. ADMISSIONS REQUIREMENT	31%	40%	5%	16%	8%	21%	19%	21%	19%	19%	40%	36%	0%	12%	12%	37%	30%	7%	12%	14%
6. REGISTRATION FOR TEACHING	28%	23%	8%	14%	26%	20%	20%	19%	21%	19%	28%	20%	8%	24%	20%	27%	20%	6%	21%	27%
7. ADVISORY COMMITTEES	30%	44%	9%	6%	10%	19%	23%	19%	19%	19%	36%	40%	12%	4%	8%	32%	38%	8%	13%	9%
8. QUALITY GOALS	22%	33%	11%	21%	13%	19%	22%	20%	19%	19%	28%	32%	4%	28%	8%	22%	24%	12%	29%	12%
9. UNIVERSITY ENVIRONMENT	29%	43%	12%	7%	9%	20%	21%	20%	19%	19%	32%	52%	4%	8%	4%	29%	48%	8%	7%	8%
10. CONTINUING EDUCATION	24%	42%	14%	13%	8%	19%	22%	20%	19%	19%	8%	52%	16%	20%	4%	22%	42%	18%	9%	9%
11. COMPETITIVENESS	64%	30%	5%	1%	1%	21%	21%	19%	19%	19%	60%	36%	0%	4%	0%	61%	31%	6%	1%	1%
12. NATIONAL SCIENCE BOARD	62%	28%	9%	1%	0%	19%	22%	20%	19%	19%	50%	46%	4%	0%	0%	62%	29%	8%	1%	0%
D1. LIMITING PROGRAMS	24%	32%	10%	15%	20%	20%	22%	20%	20%	20%	26%	37%	0%	11%	26%	16%	28%	5%	20%	31%
D2. MORATORIUM ON PhD PROGRAMS	13%	22%	5%	25%	35%	20%	21%	20%	20%	21%	11%	21%	5%	37%	26%	12%	19%	2%	26%	41%
D3. MORATORIUM ON NEW SCHOOLS	24%	19%	7%	19%	32%	20%	21%	20%	21%	20%	28%	17%	6%	22%	28%	15%	19%	5%	22%	39%
D4. REGISTRATION FOR TEACHING (1st)	28%	18%	2%	17%	36%	21%	21%	20%	20%	20%	39%	11%	11%	11%	28%	25%	19%	4%	20%	32%
D5. QUALITY GOALS	13%	26%	7%	33%	21%	20%	21%	20%	21%	20%	11%	28%	17%	28%	17%	9%	21%	10%	27%	32%
D6. CONTINUING EDUCATION	18%	48%	10%	11%	14%	20%	21%	21%	20%	20%	22%	56%	6%	6%	11%	17%	51%	9%	14%	9%
D7. MINORITIES & WOMEN	20%	31%	5%	17%	27%	21%	20%	20%	20%	21%	17%	33%	11%	11%	28%	24%	22%	4%	23%	27%
D8. DR. OF ENG. AS 1st PROFESSIONAL DEGREE	10%	23%	11%	16%	40%	20%	21%	21%	20%	20%	22%	33%	6%	6%	33%	13%	25%	9%	14%	39%
D9. REGISTRATION FOR TEACHING (NCEE)	25%	8%	4%	20%	44%	21%	20%	20%	21%	20%	33%	11%	6%	11%	39%	19%	14%	6%	13%	48%

ROLE OF TECHNOLOGY	Administration					Eng. Design & Prod.					Research/Devel.					Teaching				
1. FOCUS ON TEACHING	76%	23%	1%	1%	0%	21%	20%	20%	19%	19%	73%	27%	0%	0%	0%	73%	26%	1%	0%	0%
2. LABORATORY EXPERIENCE	74%	26%	0%	0%	0%	21%	21%	19%	19%	19%	86%	14%	0%	0%	0%	72%	27%	0%	1%	0%
3. LIBRARY	61%	37%	2%	0%	0%	20%	21%	20%	19%	19%	77%	14%	9%	0%	0%	59%	36%	4%	1%	0%
4. LIFE-LONG LEARNING	63%	30%	2%	3%	2%	20%	20%	21%	19%	19%	68%	23%	0%	5%	5%	54%	35%	4%	5%	2%
RESOURCE ALLOCATIONS																				
1. INDUSTRY FINANCIAL SUPPORT	71%	27%	1%	1%	0%	20%	21%	20%	19%	19%	64%	32%	0%	5%	0%	75%	23%	1%	0%	0%
2. COMPUTER MAINTENANCE	68%	29%	2%	0%	1%	19%	21%	21%	19%	19%	62%	24%	10%	0%	5%	68%	23%	6%	3%	0%
3. DONATED EQUIPMENT	57%	36%	5%	2%	0%	19%	21%	21%	19%	19%	59%	32%	5%	5%	0%	56%	36%	4%	4%	1%
4. UTILIZE REGIONAL LABORATORIES	14%	31%	31%	12%	11%	20%	20%	22%	20%	20%	26%	42%	16%	11%	5%	14%	34%	32%	19%	2%
5. TECHNICAL STAFF TRAINED BY INDUSTRY	36%	42%	17%	2%	3%	20%	20%	22%	20%	20%	32%	47%	11%	5%	5%	32%	46%	16%	4%	4%
ACCREDITATION CRITERIA																				
1. LABORATORY REQUIRMENT	36%	44%	9%	6%	5%	19%	23%	19%	19%	19%	14%	64%	14%	0%	9%	32%	43%	13%	4%	8%
2. COMPUTER REQUIREMENT	31%	47%	10%	6%	6%	19%	23%	19%	19%	19%	14%	59%	18%	0%	9%	30%	42%	13%	6%	9%
3. "STRAWMAN" CRITERIA	15%	38%	20%	14%	13%	19%	21%	20%	20%	19%	5%	43%	29%	10%	14%	10%	38%	22%	16%	14%
C1. SPECIFIC CRITERIA	36%	38%	1%	14%	11%	20%	21%	21%	20%	20%	30%	35%	0%	15%	20%	38%	29%	1%	17%	15%

NC2E-NATIONAL CONGRESS ON ENGINEERING EDUCATION

RESOLUTION STATISTICS: BROKEN DOWN BY AREA OF MAJOR ACTIVITY

	ENG. ED.					ENG. PRACTICE					ENG. POLICY					NON-ENGINEERING				
FACULTY RESOLUTIONS	SA	GA	N	GD	SD	SA	GA	N	GD	SD	SA	GA	N	GD	SD	SA	GA	N	GD	SD
1. GRADUATE PROGRAM ATTRACTIVENESS	29%	42%	14%	11%	5%	17%	57%	24%	2%	0%	17%	67%	10%	0%	7%	33%	67%	0%	0%	0%
2. GRADUATE SUPPORT	59%	33%	3%	3%	1%	29%	45%	21%	5%	0%	39%	55%	3%	3%	0%	100%	0%	0%	0%	0%
3. PROFICIENCY IN ENGLISH	56%	27%	5%	7%	6%	81%	17%	0%	2%	0%	68%	26%	3%	3%	0%	67%	0%	0%	0%	33%
4. THE TEACHING FUNCTION	63%	25%	4%	5%	2%	62%	36%	0%	2%	0%	53%	33%	7%	3%	3%	67%	0%	0%	0%	33%
5. TEACHING WORKSHOPS	40%	47%	12%	1%	0%	38%	45%	17%	0%	0%	39%	48%	13%	0%	0%	67%	0%	33%	0%	0%
6. ENGINEERING PRACTICE	34%	35%	9%	13%	9%	69%	24%	2%	2%	2%	47%	43%	0%	10%	0%	33%	67%	0%	0%	0%
7. BALANCED DEPARTMENTS	42%	46%	8%	3%	1%	33%	43%	24%	0%	0%	39%	45%	16%	0%	0%	67%	33%	0%	0%	0%
8. FACULTY CAREER ATTRACTIVENESS	66%	27%	4%	2%	0%	45%	40%	5%	10%	0%	53%	27%	13%	7%	0%	67%	33%	0%	0%	0%
9. PROFESSIONAL COMPETENCE	33%	40%	11%	11%	5%	48%	45%	5%	2%	0%	37%	40%	10%	7%	7%	67%	33%	0%	0%	0%
10. INTERACTION WITH INDUSTRY	63%	29%	8%	2%	0%	45%	36%	17%	2%	0%	50%	50%	0%	0%	0%	100%	0%	0%	0%	0%
11. UTILIZE FACULTY W/O DOCATORATES	26%	26%	19%	19%	9%	40%	50%	0%	5%	5%	33%	43%	10%	5%	10%	0%	100%	0%	0%	0%
A1. GRADUATE PROGRAM ATTRACTIVENESS	41%	44%	4%	6%	5%	63%	23%	3%	10%	0%	29%	54%	0%	13%	4%	50%	25%	0%	25%	0%
A2. PROFICIENCY IN ENGLISH	41%	23%	2%	8%	26%	67%	20%	3%	3%	7%	42%	29%	8%	8%	13%	25%	50%	0%	0%	25%
A3. PROFESSIONAL COMPETENCE	52%	39%	5%	2%	2%	45%	55%	0%	0%	0%	46%	42%	4%	4%	4%	50%	50%	0%	0%	0%
A4. UTILIZE FACULTY W/O DOCTORATES	44%	40%	3%	6%	7%	52%	38%	3%	3%	3%	38%	38%	17%	4%	4%	25%	75%	0%	0%	0%
CURRICULUM ISSUES																				
1. COMPUTER USE	50%	41%	5%	2%	1%	46%	38%	8%	5%	3%	55%	34%	10%	0%	0%	50%	50%	0%	0%	0%
2. MANUFACTURING & CONSTRUCTION	26%	50%	13%	9%	2%	49%	36%	13%	3%	0%	48%	52%	0%	0%	0%	60%	40%	0%	0%	0%
3. BASIC SCIENCE REQUIREMENT	30%	48%	11%	8%	2%	23%	54%	15%	8%	0%	41%	41%	14%	0%	3%	0%	60%	20%	20%	0%
4. MATHEMATICS REQUIREMENT	45%	47%	4%	2%	2%	46%	51%	0%	0%	3%	59%	41%	0%	0%	0%	20%	60%	20%	0%	0%
5. THE GLOBAL ECONOMY	25%	41%	19%	9%	6%	21%	46%	18%	13%	3%	29%	39%	21%	4%	7%	20%	80%	0%	0%	0%
6. THE INDUSTRIAL ENVIRONMENT	30%	47%	12%	6%	5%	59%	26%	5%	8%	3%	34%	52%	10%	3%	0%	40%	40%	20%	0%	0%
7. ENGINEERING SCIENCE CRITERIA	31%	44%	17%	7%	2%	26%	46%	18%	8%	3%	31%	62%	7%	0%	0%	25%	50%	25%	0%	0%
8. BASIC EDUCATION REQUIREMENT	30%	39%	14%	9%	8%	49%	28%	13%	8%	3%	32%	43%	18%	7%	0%	0%	40%	20%	20%	20%
9. ENGINEERING DESIGN CRITERIA	51%	38%	4%	4%	2%	49%	44%	3%	3%	3%	48%	48%	3%	0%	0%	20%	60%	0%	20%	0%
10. LIBERAL ARTS & HUMANITIES	30%	48%	8%	7%	8%	36%	36%	15%	13%	0%	32%	43%	21%	4%	0%	20%	40%	0%	0%	40%
11. INTERNATIONAL ACCREDITATION	17%	17%	37%	11%	17%	10%	28%	44%	5%	13%	14%	28%	41%	7%	10%	20%	20%	60%	0%	0%
12. PROFESSIONAL-LEVEL ACCREDITATION	20%	37%	16%	11%	16%	11%	37%	21%	18%	13%	22%	30%	19%	4%	26%	0%	40%	40%	0%	20%
13. ACADEMIC PROGRAM LENGTH																				
I. ENCOURAGE 5-YEAR PROGRAM	16%	16%	5%	22%	41%	26%	32%	3%	21%	18%	19%	19%	8%	15%	38%	0%	20%	60%	0%	20%
II. REDUCE TECHNICAL CONTENT	9%	14%	7%	24%	46%	13%	26%	13%	18%	31%	15%	26%	11%	7%	41%	0%	20%	40%	20%	20%
III. REINSTITUTE DUAL LEVEL	15%	17%	15%	15%	39%	32%	29%	18%	11%	11%	31%	15%	15%	12%	27%	0%	20%	40%	20%	20%
IV. PRESCRIBE 5-YEARS BY 1995	16%	11%	8%	15%	51%	29%	21%	8%	24%	18%	23%	12%	12%	12%	42%	0%	20%	40%	20%	20%

	Eng. Ed.					Eng. Practice					Eng. Policy					Non-Engineering				
14. REQUIRE STATISTICS	22%	43%	14%	8%	12%	33%	43%	17%	0%	7%	32%	50%	14%	5%	0%	20%	60%	20%	0%	0%
15. HEALTH & SAFETY	14%	32%	26%	17%	10%	10%	55%	24%	10%	0%	32%	41%	14%	9%	5%	20%	40%	40%	0%	0%
16. LANGUAGE ADMISSION REQUIREMENT	11%	28%	21%	16%	24%	21%	38%	28%	7%	7%	18%	45%	27%	0%	9%	20%	20%	0%	20%	40%
17. REQUIRE ORIENTAL LANGUAGES	8%	30%	27%	13%	21%	17%	23%	30%	27%	3%	14%	45%	27%	5%	9%	0%	20%	20%	20%	40%
18. D. ENG. AS PROFESSIONAL DEGREE	6%	11%	14%	17%	53%	14%	11%	21%	21%	32%	10%	10%	20%	25%	35%	25%	25%	25%	25%	0%
B1. INTERNATIONAL ACCREDITATION	16%	21%	22%	16%	26%	14%	17%	34%	14%	21%	13%	25%	33%	13%	17%	25%	0%	75%	0%	0%
B2. PROFESSIONAL-LEVEL ACCREDITATION	18%	33%	9%	21%	19%	24%	31%	7%	14%	24%	17%	25%	17%	21%	21%	25%	25%	25%	25%	0%
B3. REQUIRE STATISTICS	20%	37%	5%	19%	19%	41%	31%	7%	17%	3%	46%	33%	4%	8%	8%	25%	75%	0%	0%	0%
B4. HEALTH & SAFETY	24%	40%	6%	16%	14%	28%	52%	7%	10%	3%	50%	33%	8%	8%	0%	50%	25%	0%	25%	0%
B5. LANGUAGE ADMISSION REQUIREMENT	14%	20%	6%	26%	34%	14%	31%	17%	14%	24%	21%	25%	13%	21%	21%	25%	25%	25%	0%	25%
B6. MASTERY OF ENGLISH REQUIREMENT	36%	29%	6%	14%	15%	33%	50%	13%	3%	0%	42%	29%	8%	8%	13%	25%	25%	25%	0%	25%
B7. REQUIRE ORIENTAL LANGUAGES	4%	11%	13%	17%	56%	4%	21%	25%	21%	29%	4%	33%	0%	17%	46%	25%	25%	0%	25%	25%
B8. ENCOURAGE 5-YEAR PROGRAM	26%	17%	5%	20%	32%	48%	34%	3%	10%	3%	26%	22%	9%	9%	35%	0%	50%	0%	0%	50%
B9. REINSTITUTE DUAL LEVEL ACCRED.	22%	23%	7%	17%	31%	39%	29%	11%	11%	11%	22%	22%	13%	13%	30%	25%	25%	25%	0%	25%
BROAD ACADEMIC ISSUES																				
1. LIMITING PROGRAMS	20%	27%	7%	17%	29%	16%	36%	18%	13%	18%	23%	16%	23%	19%	19%	29%	29%	14%	0%	29%
2. MORATORIUM ON PhD PROGRAMS	24%	29%	7%	17%	23%	27%	27%	7%	24%	16%	27%	27%	7%	13%	27%	29%	43%	0%	0%	29%
3. MORATORIUM ON NEW SCHOOLS	31%	22%	9%	18%	20%	31%	27%	11%	18%	13%	33%	13%	17%	13%	23%	14%	14%	0%	29%	43%
4. FACULTY & LAB REQUIREMENTS	33%	37%	8%	13%	9%	27%	64%	7%	0%	2%	40%	43%	10%	7%	0%	29%	43%	14%	0%	14%
5. ADMISSIONS REQUIREMENTS	35%	33%	6%	15%	11%	38%	40%	13%	7%	2%	50%	40%	7%	3%	0%	29%	57%	0%	0%	14%
6. REGISTRATION FOR TEACHING	27%	27%	6%	15%	25%	49%	18%	11%	11%	11%	45%	13%	3%	13%	26%	14%	29%	0%	29%	29%
7. ADVISORY COMMITTEES	31%	40%	9%	9%	10%	40%	47%	7%	2%	4%	40%	37%	10%	3%	10%	29%	43%	29%	0%	0%
8. QUALITY GOALS	20%	30%	13%	24%	13%	27%	49%	9%	13%	2%	23%	43%	7%	17%	10%	14%	57%	14%	14%	0%
9. UNIVERSITY ENVIRONMENT	34%	39%	11%	7%	9%	44%	44%	11%	0%	0%	30%	53%	7%	3%	7%	14%	71%	14%	0%	0%
10. CONTINUING EDUCATION	21%	44%	15%	11%	9%	30%	34%	16%	11%	9%	37%	23%	13%	20%	7%	57%	43%	0%	0%	0%
11. COMPETITIVENESS	65%	28%	5%	1%	1%	67%	29%	2%	2%	0%	71%	26%	0%	3%	0%	57%	14%	29%	0%	0%
12. NATIONAL SCIENCE BOARD	63%	26%	10%	1%	0%	53%	31%	16%	0%	0%	64%	25%	11%	0%	0%	57%	14%	29%	0%	0%
B1. LIMITING PROGRAMS	22%	26%	8%	20%	25%	36%	36%	7%	11%	11%	26%	57%	13%	4%	0%	0%	25%	25%	0%	50%
B2. MORATORIUM ON PhD PROGRAMS	13%	21%	4%	24%	38%	18%	36%	4%	25%	18%	13%	17%	9%	30%	30%	0%	25%	0%	25%	50%
B3. MORATORIUM ON NEW SCHOOLS	21%	19%	7%	18%	35%	22%	26%	7%	26%	19%	22%	17%	4%	30%	26%	0%	25%	0%	25%	50%
B4. REGISTRATION FOR TEACHING (1st)	28%	18%	3%	19%	32%	37%	22%	0%	11%	30%	30%	9%	0%	26%	35%	0%	0%	0%	25%	75%
B5. QUALITY GOALS	11%	24%	7%	30%	27%	8%	38%	0%	35%	19%	13%	43%	4%	13%	26%	0%	25%	0%	50%	25%
B6. CONTINUING EDUCATION	19%	48%	10%	11%	11%	19%	41%	19%	15%	7%	13%	57%	4%	17%	9%	0%	75%	25%	0%	0%
B7. MINORITIES & WOMEN	22%	28%	5%	20%	25%	4%	30%	7%	22%	37%	9%	36%	5%	32%	18%	50%	0%	25%	0%	25%
B8. DR. OF ENG. AS 1st PROFESSIONAL DEGREE	12%	23%	9%	14%	42%	19%	15%	19%	8%	38%	5%	24%	14%	14%	43%	0%	50%	0%	25%	25%
B9. REGISTRATION FOR TEACHING (NCEE)	22%	12%	5%	16%	45%	44%	7%	0%	11%	37%	26%	9%	0%	13%	52%	0%	0%	0%	50%	50%

LABORATORY, COMPUTER, AND EDUCATIONAL TECHNOLOGY ISSUES

ROLE OF TECHNOLOGY	Eng. Ed.					Eng. Practice					Eng. Policy					Non-Engineering				
1. FOCUS ON TEACHING	75%	23%	1%	1%	1%	69%	29%	3%	0%	0%	82%	18%	0%	0%	0%	100%	0%	0%	0%	0%
2. LABORATORY EXPERIENCE	75%	25%	0%	1%	0%	71%	26%	0%	0%	3%	82%	18%	0%	0%	0%	100%	0%	0%	0%	0%
3. LIBRARY	61%	36%	2%	1%	0%	54%	34%	11%	0%	0%	68%	29%	4%	0%	0%	50%	50%	0%	0%	0%
4. LIFE-LONG LEARNING	61%	31%	3%	4%	2%	63%	31%	6%	0%	0%	75%	18%	4%	4%	0%	50%	50%	0%	0%	0%
RESOURSE ALLOCATIONS																				
1. INDUSTRY FINANCIAL SUPPORT	77%	21%	1%	1%	0%	41%	53%	3%	3%	0%	54%	46%	0%	0%	0%	50%	50%	0%	0%	0%
2. COMPUTER MAINTENANCE	70%	24%	5%	1%	1%	38%	44%	15%	0%	3%	59%	30%	4%	4%	4%	50%	50%	0%	0%	0%
3. DONATED EQUIPMENT	58%	34%	5%	2%	1%	32%	53%	9%	6%	0%	33%	56%	7%	4%	0%	50%	50%	0%	0%	0%
4. UTILIZE REGIONAL LABORATORIES	16%	34%	27%	13%	9%	29%	21%	29%	17%	4%	32%	21%	42%	5%	0%	0%	100%	0%	0%	0%
5. TECH. STAFF TRAINED BY INDUSTRY	35%	41%	19%	3%	3%	21%	33%	29%	8%	8%	21%	58%	11%	11%	0%	0%	0%	100%	0%	0%
ACCREDITATION CRITERIA																				
1. LABORATORY REQUIRMENT	37%	40%	10%	7%	6%	25%	59%	13%	0%	3%	32%	57%	7%	0%	4%	50%	50%	0%	0%	0%
2. COMPUTER REQUIREMENT	34%	43%	9%	8%	6%	22%	59%	16%	0%	3%	30%	56%	7%	0%	7%	0%	100%	0%	0%	0%
3. "STRAWMAN" CRITERIA	15%	39%	19%	15%	12%	12%	30%	45%	9%	3%	19%	38%	27%	8%	8%	0%	50%	50%	0%	0%
C1. SPECIFIC CRITERIA	37%	32%	2%	16%	13%	41%	48%	3%	7%	0%	43%	35%	4%	9%	9%	25%	75%	0%	0%	0%

NC2E - NATIONAL CONGRESS ON ENGINEERING EDUCATION

RESOLUTION RESULTS BROKEN DOWN BY "9. OTHER CHARACTERISTICS" FROM PARTICIPANT PROFILE

FACULTY RESOLUTIONS	LICENSED PROF. ENG.					OFFICER OF ENG. SOC.					MEMBER PROF./TECH. SOC.					MEMBER SOC. ED. COMMITTEE				
	SA	GA	N	GD	SD	SA	GA	N	GD	SD	SA	GA	N	GD	SD	SA	GA	N	GD	SD
1. GRADUATE PROGRAM ATTRACTIVENESS	33%	43%	12%	9%	3%	30%	44%	17%	6%	3%	27%	45%	14%	9%	5%	30%	48%	7%	11%	4%
2. GRADUATE SUPPORT	54%	39%	4%	3%	1%	52%	38%	7%	3%	0%	55%	38%	3%	4%	1%	58%	33%	2%	5%	2%
3. PROFICIENCY IN ENGLISH	62%	24%	5%	6%	3%	69%	21%	4%	4%	2%	60%	26%	3%	6%	5%	64%	26%	3%	5%	1%
4. THE TEACHING FUNCTION	60%	32%	4%	4%	1%	67%	30%	0%	2%	1%	62%	27%	4%	4%	2%	62%	27%	6%	5%	0%
5. TEACHING WORKSHOPS	39%	49%	11%	1%	0%	38%	43%	17%	1%	0%	41%	47%	11%	0%	0%	39%	52%	9%	0%	0%
6. ENGINEERING PRACTICE	46%	32%	5%	11%	5%	48%	37%	7%	6%	3%	40%	32%	9%	12%	7%	45%	33%	7%	9%	5%
7. BALANCED DEPARTMENTS	42%	46%	9%	2%	1%	40%	42%	13%	3%	1%	46%	41%	11%	1%	1%	45%	39%	13%	3%	0%
8. FACULTY CAREER ATTRACTIVENESS	60%	29%	6%	4%	1%	58%	34%	4%	4%	0%	63%	29%	4%	4%	0%	59%	28%	5%	8%	0%
9. PROFESSIONAL COMPETENCE	42%	37%	11%	7%	3%	46%	36%	7%	9%	3%	36%	41%	9%	11%	4%	44%	35%	5%	12%	4%
10. INTERACTION WITH INDUSTRY	57%	32%	9%	2%	0%	63%	25%	10%	2%	0%	60%	30%	8%	2%	0%	61%	31%	8%	0%	0%
11. UTILIZE FACULTY W/O DOCATORATES	28%	31%	14%	18%	10%	29%	25%	13%	27%	6%	29%	31%	16%	15%	9%	27%	27%	13%	22%	11%
A1. GRADUATE PROGRAM ATTRACTIVENESS	45%	39%	5%	6%	5%	46%	45%	4%	4%	2%	42%	42%	4%	7%	4%	47%	38%	5%	6%	3%
A2. PROFICIENCY IN ENGLISH	49%	25%	1%	7%	17%	59%	18%	1%	7%	15%	43%	23%	1%	9%	24%	51%	21%	3%	9%	17%
A3. PROFESSIONAL COMPETENCE	55%	37%	4%	2%	2%	58%	37%	1%	2%	1%	51%	41%	3%	2%	2%	58%	31%	5%	3%	3%
A4. UTILIZE FACULTY W/O DOCTORATES	50%	35%	4%	7%	4%	49%	38%	4%	5%	5%	43%	41%	4%	6%	6%	53%	33%	5%	6%	3%
CURRICULUM ISSUES																				
1. COMPUTER USE	50%	42%	6%	1%	2%	52%	38%	8%	1%	1%	50%	41%	6%	3%	0%	48%	44%	6%	1%	1%
2. MANUFACTURING & CONSTRUCTION	33%	49%	10%	6%	2%	37%	46%	10%	7%	1%	31%	50%	11%	7%	2%	26%	56%	8%	8%	1%
3. BASIC SCIENCE REQUIREMENT	33%	48%	9%	8%	2%	31%	44%	15%	9%	2%	31%	48%	11%	7%	2%	36%	42%	9%	10%	2%
4. MATHEMATICS REQUIREMENT	47%	47%	2%	2%	2%	46%	50%	2%	0%	2%	48%	46%	3%	2%	2%	52%	40%	4%	1%	3%
5. THE GLOBAL ECONOMY	28%	42%	17%	8%	4%	33%	43%	13%	7%	5%	26%	43%	18%	8%	6%	28%	40%	22%	6%	4%
6. THE INDUSTRIAL ENVIRONMENT	40%	45%	9%	3%	3%	42%	41%	9%	6%	3%	34%	45%	11%	6%	4%	34%	46%	11%	7%	1%
7. ENGINEERING SCIENCE CRITERIA	30%	45%	15%	8%	2%	31%	48%	15%	4%	3%	33%	44%	16%	6%	2%	33%	40%	15%	9%	3%
8. BASIC EDUCATION REQUIREMENT	33%	41%	13%	8%	5%	31%	44%	11%	10%	4%	32%	41%	14%	7%	5%	35%	36%	18%	8%	3%
9. ENGINEERING DESIGN CRITERIA	56%	38%	1%	3%	2%	55%	36%	4%	3%	2%	53%	38%	3%	4%	2%	58%	31%	3%	4%	3%
10. LIBERAL ARTS & HUMANITIES	32%	47%	8%	7%	6%	36%	44%	9%	8%	3%	31%	47%	9%	7%	6%	35%	42%	9%	9%	4%
11. INTERNATIONAL ACCREDITATION	17%	22%	39%	10%	12%	13%	30%	34%	9%	15%	18%	20%	39%	9%	14%	11%	25%	41%	9%	13%
12. PROFESSIONAL-LEVEL ACCREDITATION	20%	40%	16%	11%	13%	17%	36%	16%	17%	15%	20%	36%	17%	10%	17%	23%	34%	15%	13%	14%
13. ACADEMIC PROGRAM LENGTH																				
I. ENCOURAGE 5-YEAR PROGRAM	22%	20%	5%	20%	33%	23%	18%	6%	19%	34%	19%	17%	6%	21%	37%	24%	10%	5%	26%	35%
II. REDUCE TECHNICAL CONTENT	11%	17%	7%	24%	41%	10%	17%	11%	22%	41%	10%	17%	8%	21%	43%	11%	18%	10%	19%	42%
III. REINSTITUTE DUAL LEVEL	24%	17%	15%	15%	27%	28%	20%	17%	8%	27%	20%	18%	15%	14%	34%	29%	21%	9%	9%	32%
IV. PRESCRIBE 5-YEARS BY 1995	23%	14%	10%	16%	37%	24%	14%	8%	16%	38%	19%	13%	9%	16%	43%	26%	11%	5%	14%	43%

E-9

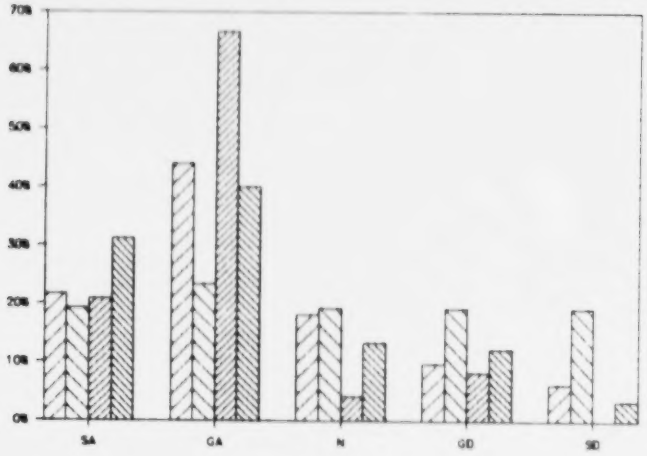
	Licensed Prof. Engineer					Officer of Eng. Society					Member of Prof/Tech Soc.					Member Soc. Education Comm.				
14. REQUIRE STATISTICS	25%	41%	17%	7%	10%	29%	39%	14%	5%	13%	24%	43%	16%	7%	10%	24%	42%	16%	5%	13%
15. HEALTH & SAFETY	18%	33%	26%	15%	8%	15%	45%	20%	9%	11%	16%	34%	28%	14%	8%	21%	34%	25%	13%	8%
16. LANGUAGE ADMISSION REQUIREMENT	13%	33%	21%	15%	18%	13%	35%	27%	10%	15%	13%	31%	21%	13%	22%	13%	33%	28%	8%	17%
17. REQUIRE ORIENTAL LANGUAGES	9%	29%	31%	16%	15%	10%	33%	28%	14%	15%	9%	29%	28%	14%	19%	9%	32%	30%	13%	16%
18. D. ENG. AS PROFESSIONAL DEGREE	6%	13%	17%	21%	43%	9%	14%	19%	14%	45%	7%	12%	15%	18%	48%	6%	14%	16%	22%	42%
B1. INTERNATIONAL ACCREDITATION	19%	20%	26%	15%	21%	17%	21%	25%	17%	20%	17%	22%	25%	13%	23%	16%	23%	29%	13%	20%
B2. PROFESSIONAL-LEVEL ACCREDITATION	24%	32%	7%	23%	14%	25%	31%	11%	14%	18%	19%	33%	10%	21%	17%	24%	33%	9%	18%	18%
B3. REQUIRE STATISTICS	25%	37%	5%	18%	15%	29%	38%	5%	12%	17%	25%	37%	4%	19%	15%	31%	36%	4%	15%	14%
B4. SAFETY AND HEALTH	28%	42%	6%	13%	12%	27%	50%	6%	6%	11%	27%	39%	6%	16%	12%	30%	46%	4%	14%	6%
B5. LANGUAGE ADMISSION REQUIREMENT	18%	24%	7%	23%	28%	17%	24%	10%	21%	29%	15%	21%	8%	24%	33%	21%	24%	6%	25%	24%
B6. MASTERY OF ENGLISH REQUIREMENT	38%	29%	6%	11%	15%	47%	28%	8%	12%	5%	36%	29%	7%	13%	15%	46%	29%	8%	11%	6%
B7. REQUIRE ORIENTAL LANGUAGES	4%	13%	13%	18%	51%	2%	18%	11%	15%	54%	3%	14%	11%	17%	55%	3%	16%	11%	13%	58%
B8. ENCOURAGE 5-YEAR PROGRAM	34%	19%	4%	18%	24%	41%	18%	5%	13%	23%	28%	19%	5%	18%	31%	39%	18%	3%	15%	25%
B9. REINSTATE DUAL LEVEL ACCRED.	29%	26%	7%	16%	22%	33%	16%	12%	13%	26%	24%	24%	7%	15%	29%	35%	20%	6%	13%	25%
BROAD ACADEMIC ISSUES																				
1. LIMITING PROGRAMS	23%	29%	10%	16%	21%	21%	32%	14%	12%	21%	20%	30%	8%	15%	27%	23%	29%	10%	13%	24%
2. MORATORIUM ON PhD PROGRAMS	28%	29%	7%	16%	20%	20%	38%	7%	18%	18%	25%	30%	7%	16%	23%	26%	31%	6%	16%	21%
3. MORATORIUM ON NEW SCHOOLS	34%	24%	9%	17%	17%	32%	23%	16%	15%	14%	32%	21%	10%	17%	20%	33%	21%	10%	18%	17%
4. FACULTY & LAB REQUIREMENTS	37%	42%	6%	10%	6%	35%	44%	8%	9%	5%	34%	39%	8%	11%	8%	39%	39%	7%	10%	4%
5. ADMISSIONS REQUIREMENTS	41%	35%	6%	9%	9%	40%	34%	7%	11%	8%	40%	31%	6%	13%	10%	41%	28%	9%	16%	6%
6. REGISTRATION FOR TEACHING	43%	28%	4%	13%	13%	43%	25%	3%	10%	19%	31%	26%	6%	13%	23%	34%	27%	6%	19%	14%
7. ADVISORY COMMITTEES	34%	40%	10%	9%	7%	36%	42%	7%	11%	4%	33%	41%	9%	8%	9%	34%	40%	8%	11%	7%
8. QUALITY GOALS	21%	33%	15%	22%	10%	25%	30%	13%	25%	7%	22%	33%	11%	23%	11%	25%	33%	10%	23%	9%
9. UNIVERSITY ENVIRONMENT	39%	38%	11%	6%	5%	39%	39%	13%	3%	6%	36%	40%	12%	5%	8%	32%	48%	10%	3%	6%
10. CONTINUING EDUCATION	25%	39%	13%	13%	10%	20%	38%	16%	14%	12%	25%	41%	13%	11%	9%	28%	38%	12%	12%	10%
11. COMPETITIVENESS	67%	27%	5%	2%	0%	70%	25%	4%	1%	0%	66%	28%	4%	1%	1%	70%	26%	3%	1%	0%
12. NATIONAL SCIENCE BOARD	60%	25%	13%	1%	0%	61%	27%	12%	1%	0%	61%	26%	13%	0%	0%	65%	25%	9%	1%	0%
B1. LIMITING PROGRAMS	28%	28%	9%	17%	18%	33%	21%	10%	15%	20%	24%	28%	9%	16%	23%	36%	29%	5%	14%	17%
B3. MORATORIUM ON PhD PROGRAMS	15%	24%	5%	24%	32%	14%	26%	4%	20%	36%	14%	23%	4%	23%	36%	15%	27%	4%	21%	32%
B3. MORATORIUM ON NEW SCHOOLS	24%	22%	7%	18%	29%	25%	18%	8%	19%	30%	23%	19%	5%	18%	35%	29%	17%	6%	19%	30%
B4. REGISTRATION FOR TEACHING (1st)	41%	19%	1%	20%	19%	42%	18%	4%	16%	20%	30%	16%	2%	19%	32%	43%	16%	5%	13%	23%
B5. QUALITY GOALS	14%	23%	6%	35%	22%	12%	23%	7%	29%	28%	12%	25%	6%	32%	26%	16%	27%	5%	27%	25%
B6. CONTINUING EDUCATION	23%	46%	10%	12%	10%	16%	47%	17%	10%	10%	18%	47%	10%	12%	12%	20%	49%	10%	11%	11%
B7. MINORITIES & WOMEN	18%	28%	7%	22%	25%	17%	21%	7%	22%	32%	19%	29%	6%	20%	26%	18%	35%	9%	13%	24%
B8. DR. ENG. 1st PROF. DEGREE	14%	23%	12%	13%	37%	21%	15%	12%	14%	38%	13%	20%	10%	15%	41%	16%	21%	9%	13%	41%
B9. REGISTRATION FOR TEACHING (NCEE)	35%	16%	4%	13%	32%	37%	11%	6%	7%	39%	26%	12%	2%	15%	45%	39%	8%	5%	14%	34%

LABORATORY, COMPUTER, AND EDUCATIONAL TECHNOLOGY ISSUES

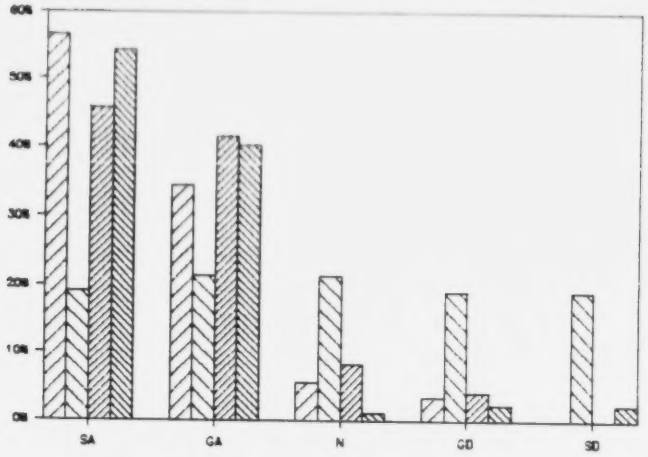
ROLE OF TECHNOLOGY	Licensed Prof. Engineer					Officer of Eng. Society					Member of Prof/Tech Soc.					Member Soc. Education Comm.				
1. FOCUS ON TEACHING	76%	22%	1%	1%	1%	77%	20%	1%	1%	1%	78%	20%	2%	1%	1%	80%	17%	2%	1%	0%
2. LABORATORY EXPERIENCE	74%	25%	0%	1%	1%	79%	20%	0%	0%	1%	74%	25%	0%	1%	1%	72%	28%	0%	0%	0%
3. LIBRARY	61%	36%	3%	0%	0%	64%	32%	3%	0%	0%	61%	35%	4%	1%	0%	59%	35%	5%	1%	0%
4. LIFE-LONG LEARNING	65%	27%	4%	3%	1%	69%	26%	2%	2%	0%	63%	30%	3%	3%	2%	57%	36%	2%	2%	2%
RESOURCE ALLOCATIONS																				
1. INDUSTRY FINANCIAL SUPPORT	69%	28%	2%	1%	0%	67%	27%	3%	2%	0%	70%	28%	1%	1%	0%	69%	28%	2%	1%	0%
2. COMPUTER MAINTENANCE	66%	27%	5%	2%	0%	64%	28%	7%	1%	0%	64%	29%	4%	2%	1%	68%	23%	5%	2%	1%
3. DONATED EQUIPMENT	51%	39%	6%	3%	1%	50%	44%	6%	0%	0%	53%	38%	5%	3%	1%	50%	40%	6%	2%	1%
4. UTILIZE REGIONAL LABORATORIES	17%	34%	28%	14%	6%	18%	18%	34%	21%	10%	18%	32%	30%	13%	7%	17%	29%	28%	17%	9%
5. TECHNICAL STAFF TRAINED BY INDUSTRY	31%	41%	25%	3%	1%	23%	43%	23%	3%	7%	30%	44%	21%	3%	2%	30%	38%	24%	6%	2%
ACCREDITATION CRITERIA																				
1. LABORATORY REQUIREMENT	36%	45%	9%	6%	4%	45%	39%	11%	4%	2%	35%	45%	10%	5%	5%	42%	35%	10%	6%	6%
2. COMPUTER REQUIREMENT	33%	47%	10%	6%	4%	41%	39%	13%	4%	4%	31%	48%	11%	5%	6%	40%	35%	10%	5%	9%
3. "STRAWMAN" CRITERIA	17%	38%	23%	13%	8%	26%	37%	20%	9%	8%	15%	37%	24%	13%	11%	19%	33%	25%	11%	11%
C1. SPECIFIC CRITERIA	41%	36%	3%	12%	9%	40%	38%	1%	11%	11%	37%	35%	2%	13%	12%	37%	34%	1%	13%	14%

FACULTY RESOLUTIONS

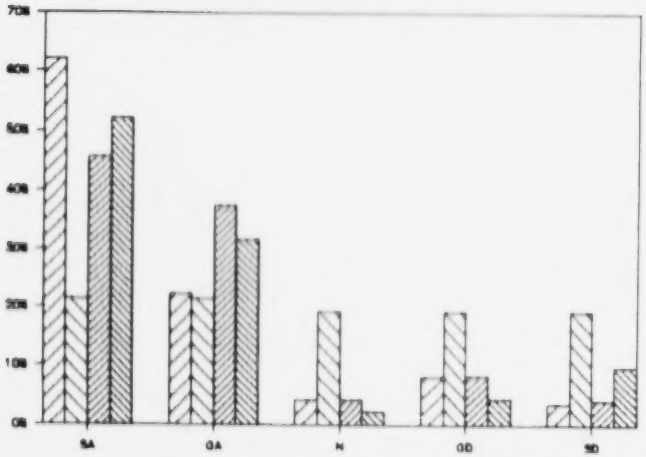
1. GRADUATE PROGRAM ATTRACTIVENESS



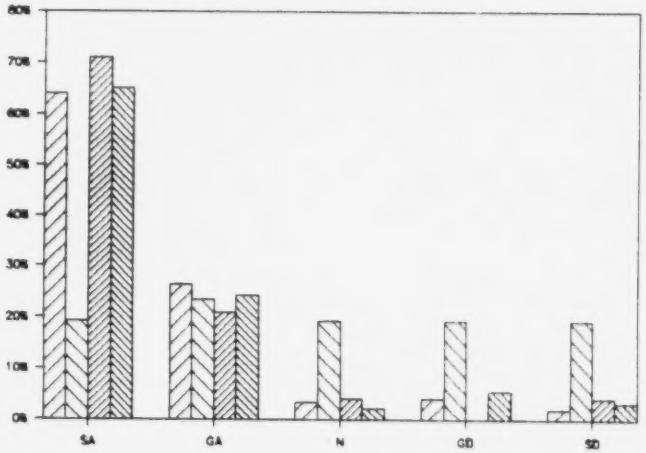
2. GRADUATE SUPPORT



3. PROFICIENCY IN ENGLISH



4. THE TEACHING FUNCTION



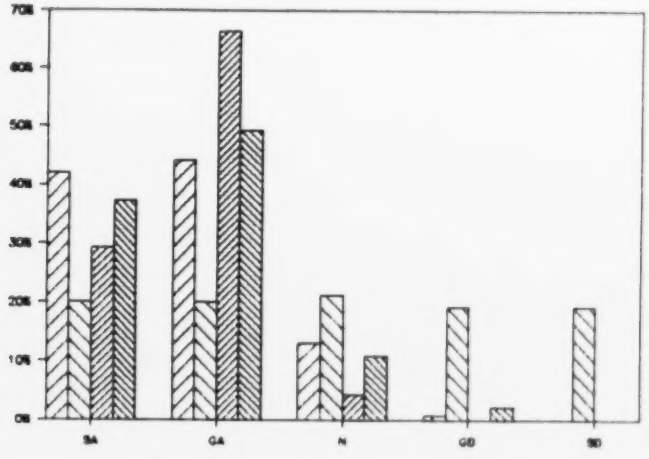
Administration

Eng. Design/Production

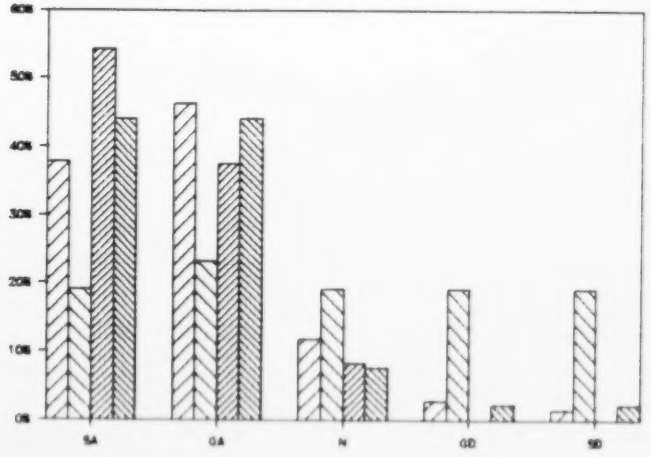
Research/Development

Teaching

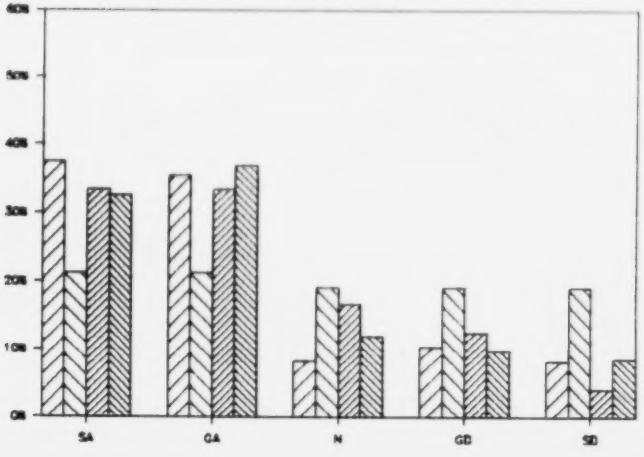
5. TEACHING WORKSHOPS



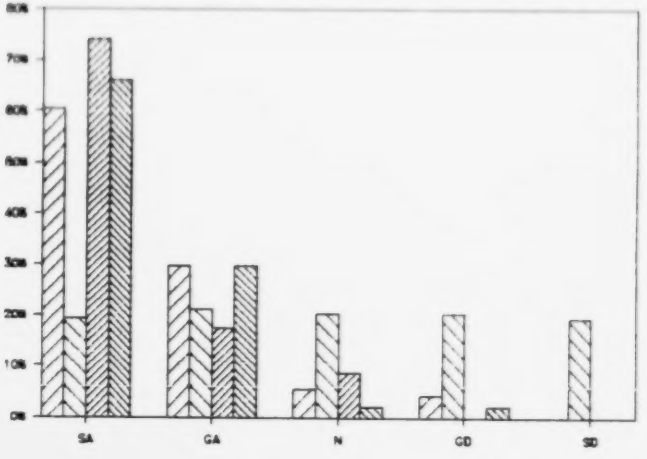
7. BALANCED DEPARTMENTS



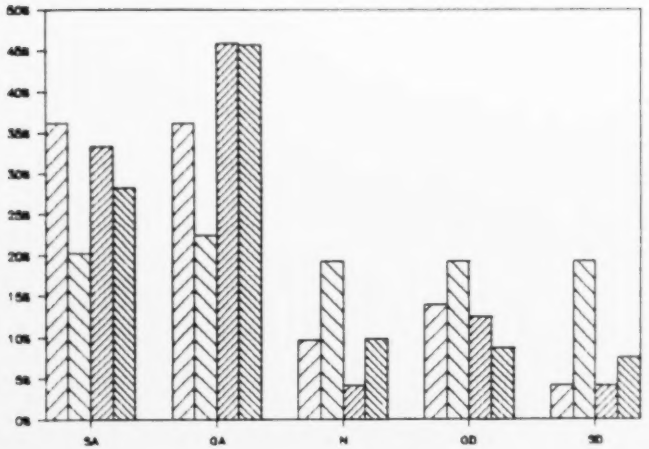
6. ENGINEERING PRACTICE



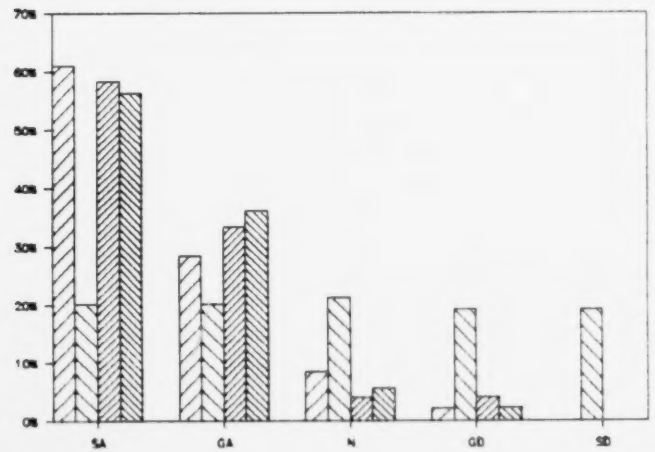
8. FACULTY CAREER ATTRACTIVENESS



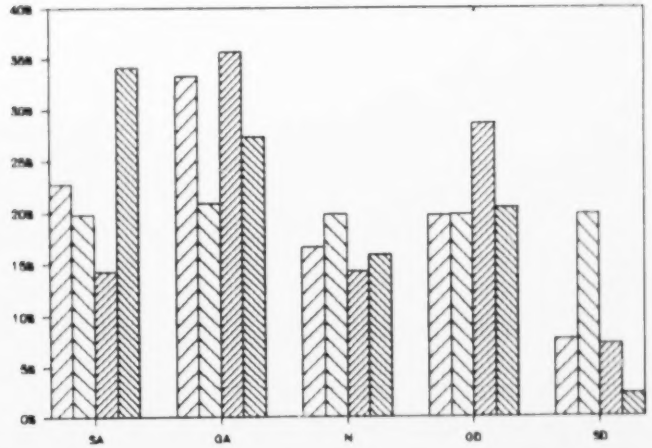
9. PROFESSIONAL COMPETENCE



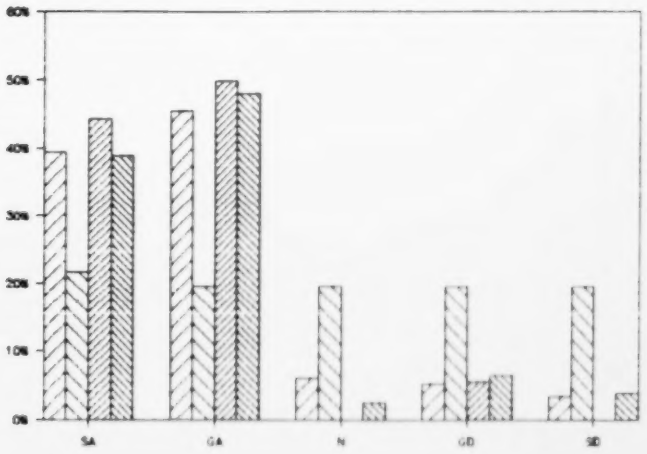
10. INTERACTION WITH INDUSTRY



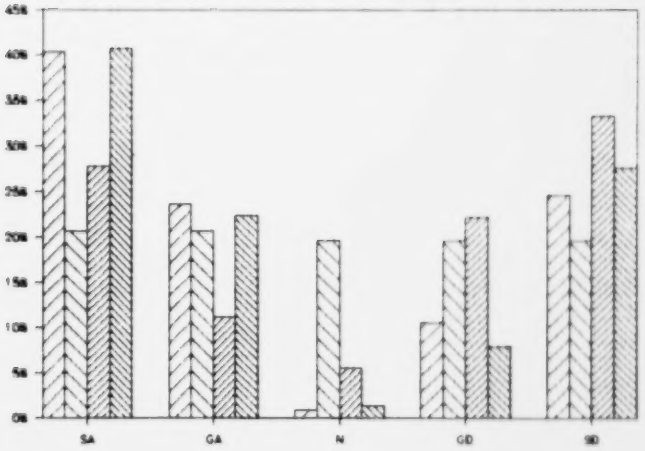
11. UTILIZE FACULTY W/O DOCTORATES



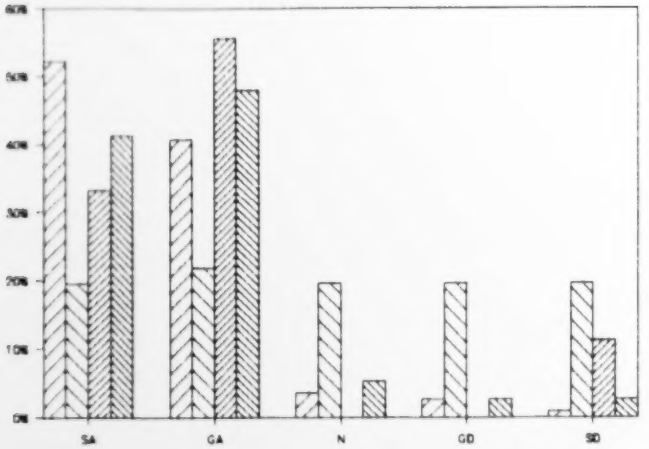
A1. GRADUATE PROGRAM ATTRACTIVENESS



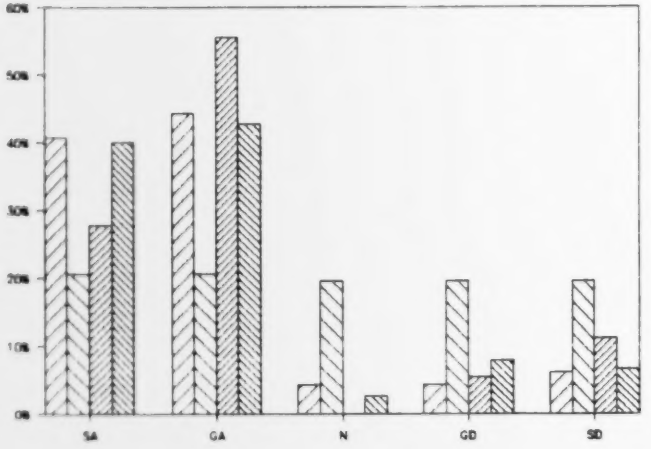
A2. PROFICIENCY IN ENGLISH



A3. PROFESSIONAL COMPETENCE

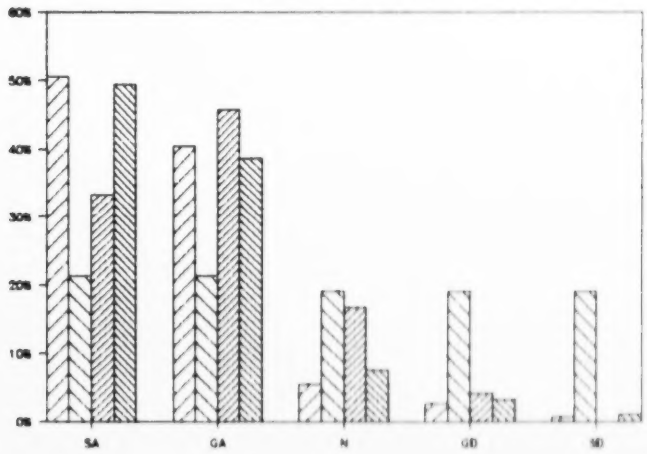


A4. UTILIZE FACULTY W/O DOCTORATES

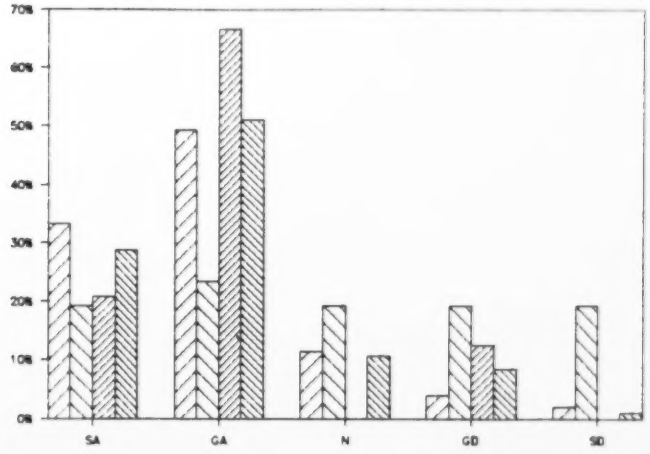


CURRICULUM ISSUES

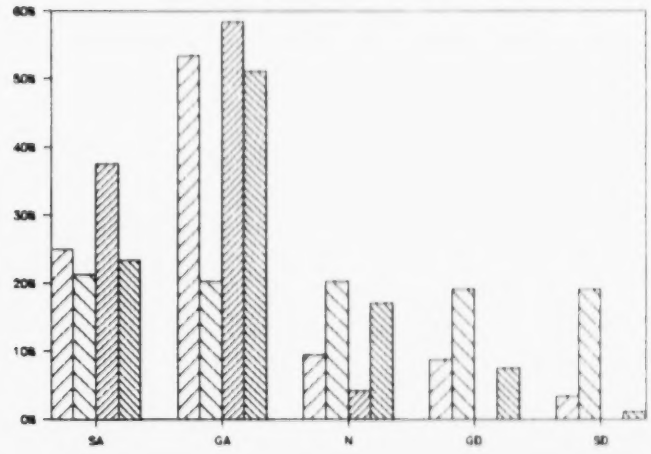
1. COMPUTER USE



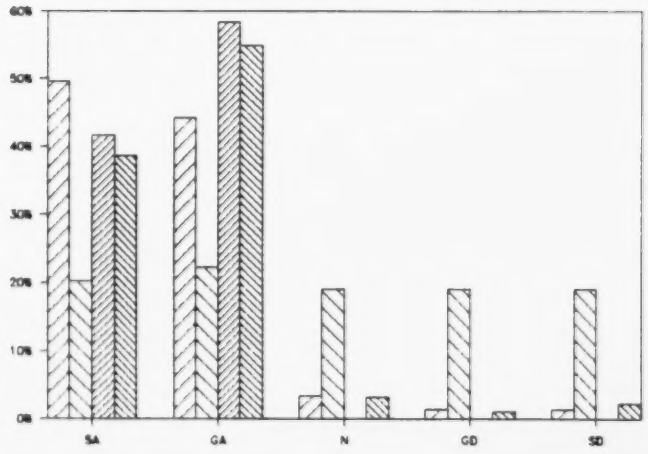
3. BASIC SCIENCE REQUIREMENT



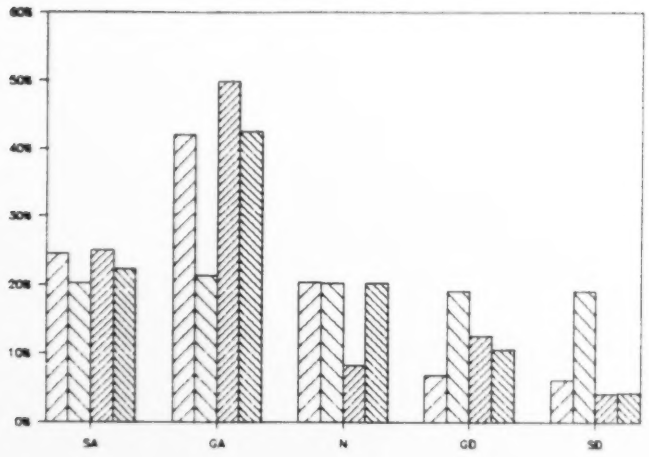
2. MANUFACTURING & CONSTRUCTION



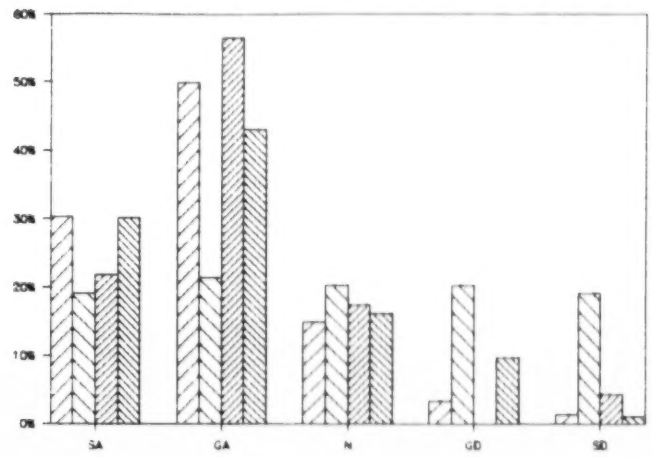
4. MATHEMATICS REQUIREMENT



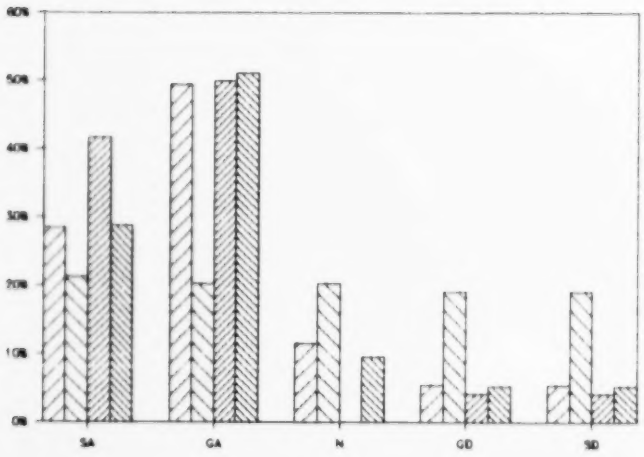
5. THE GLOBAL ECONOMY



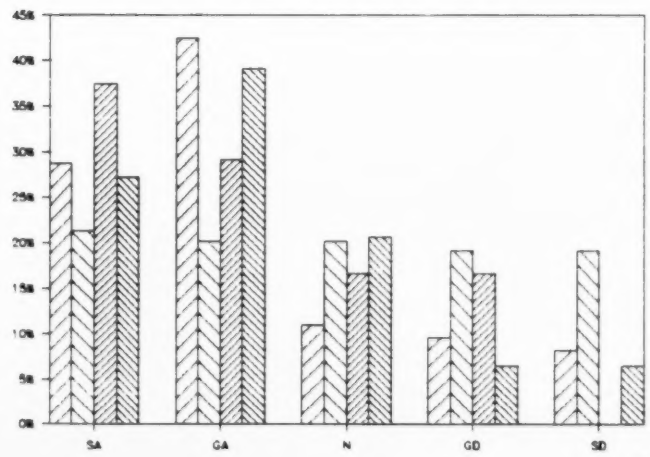
7. ENGINEERING SCIENCE CRITERIA



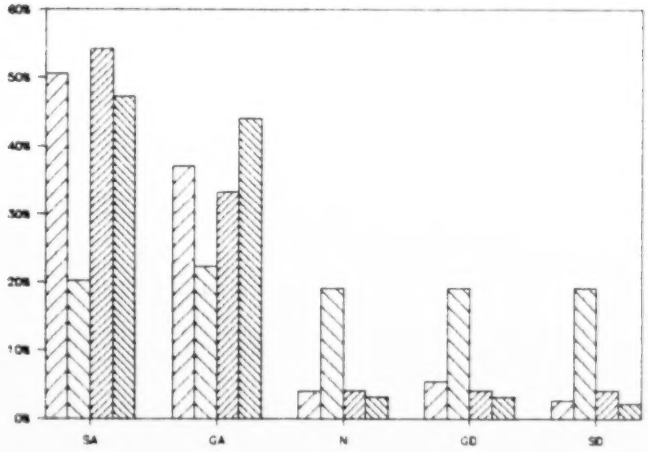
6. THE INDUSTRIAL ENVIRONMENT



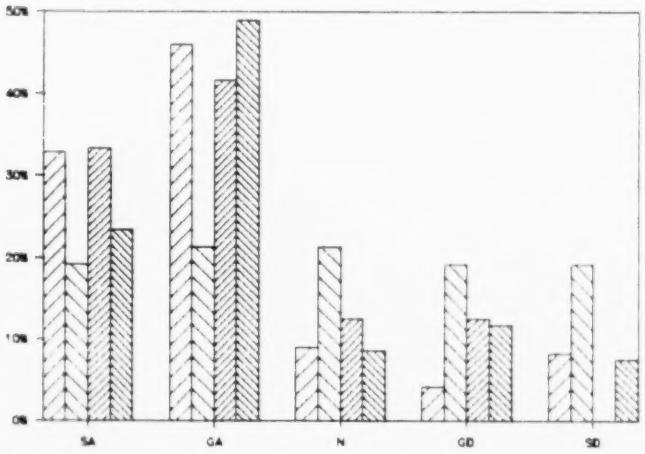
8. BASIC EDUCATION CRITERIA



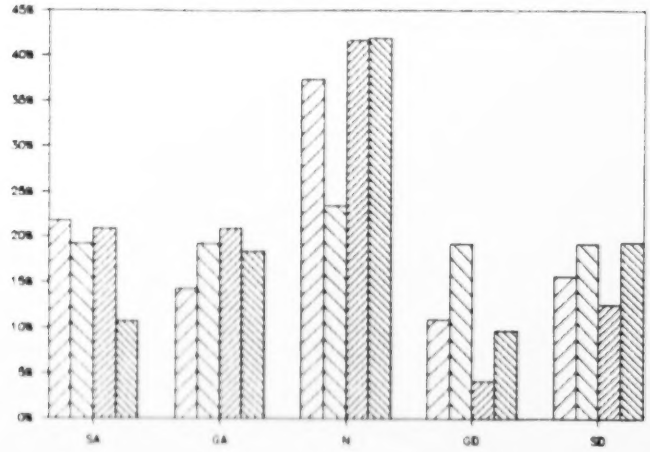
9. ENGINEERING DESIGN CRITERIA



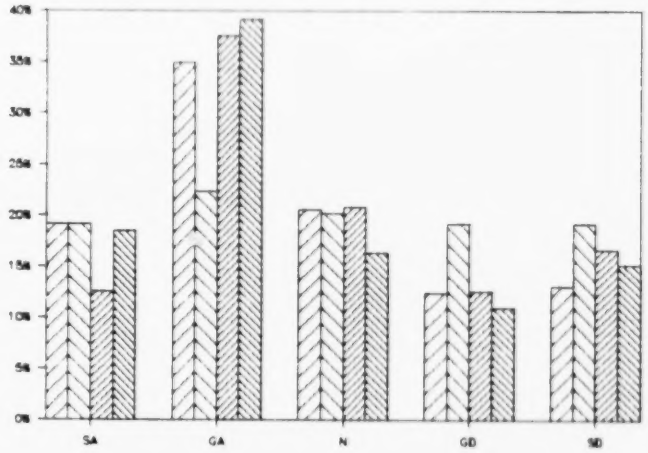
10. LIBERAL ARTS & HUMANITIES



11. INTERNATIONAL ACCREDITATION

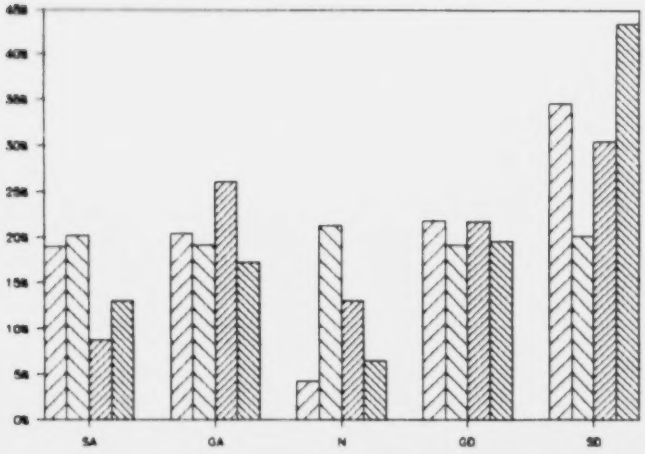


12. PROFESSIONAL-LEVEL ACCREDITATION

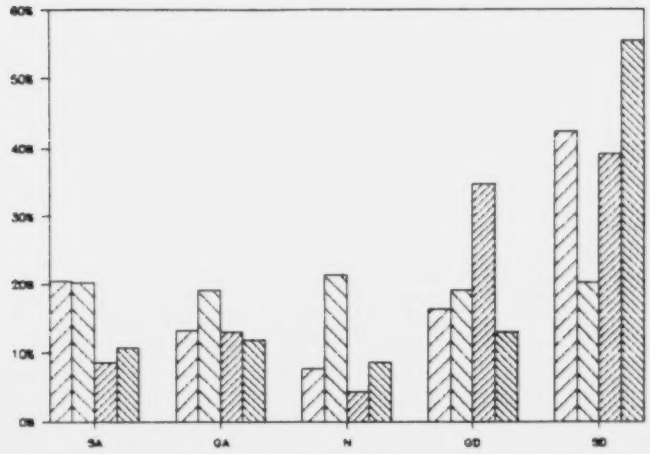


13. ACADEMIC PROGRAM LENGTH

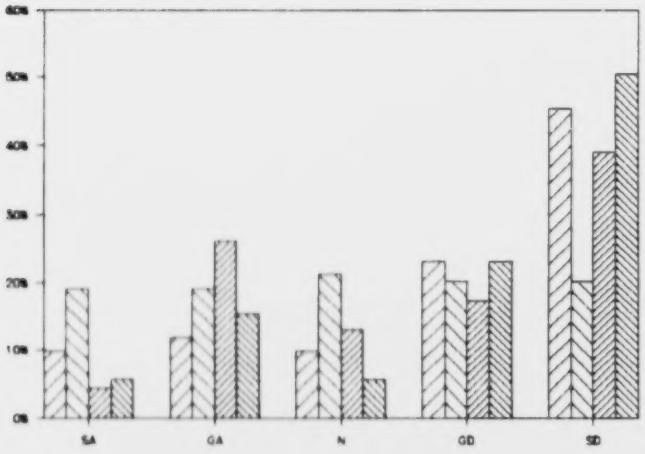
13. I. ENCOURAGE 5-YEAR PROGRAM



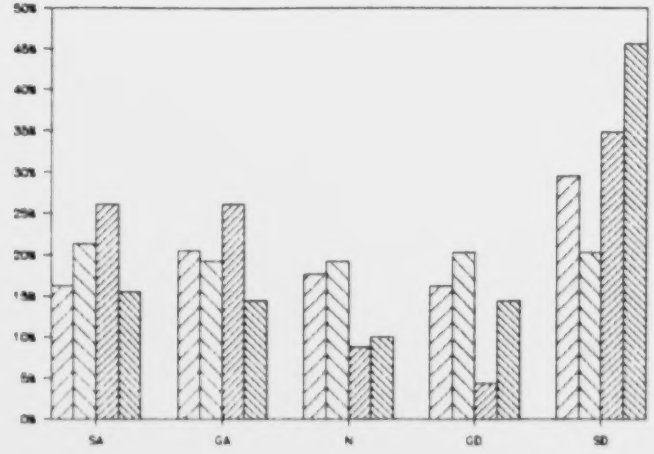
13. IV. PRESCRIBE 5-YEARS BY 1995



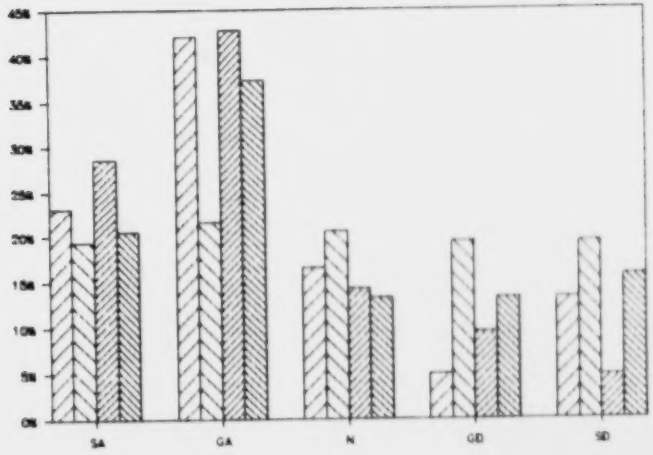
13. II. REDUCE TECHNICAL CONTENT



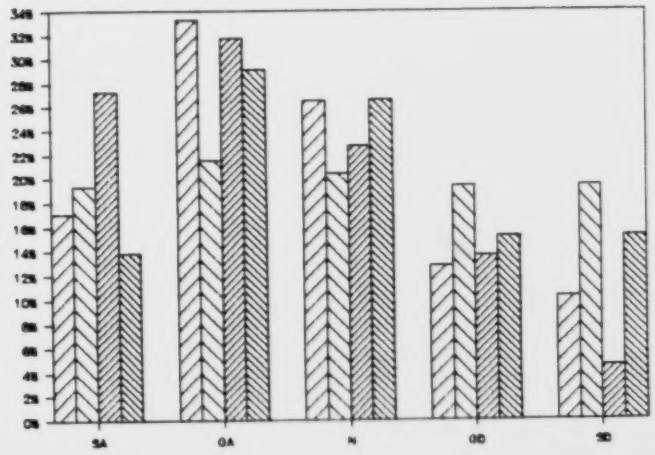
13. III. REINSTITUTE DUAL LEVEL



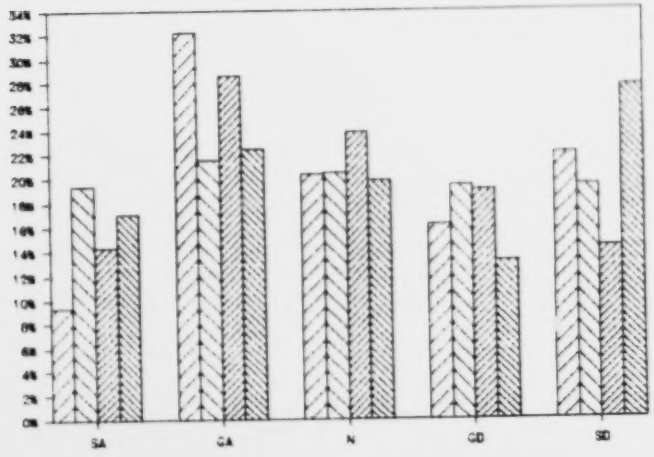
14. REQUIRE STATISTICS



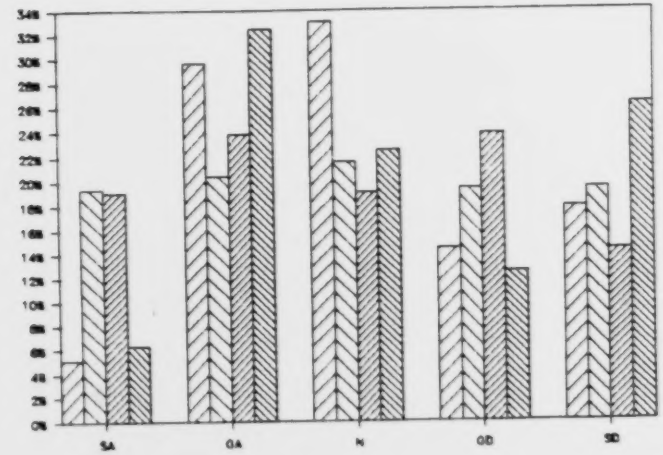
15. HEALTH & SAFETY



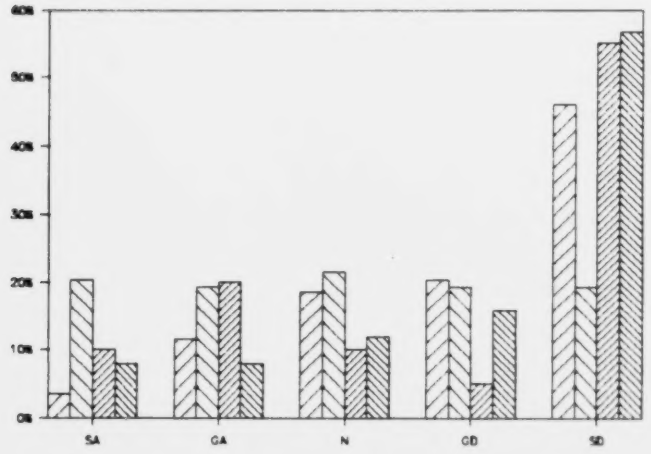
16. LANGUAGE ADMISSION REQUIREMENT



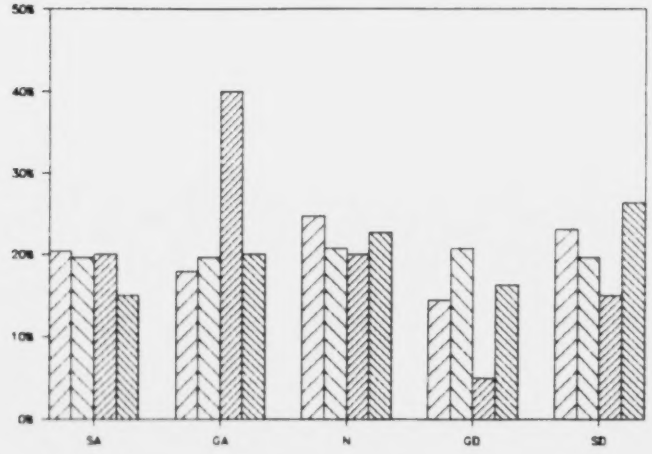
17. REQUIRE ORIENTAL LANGUAGES



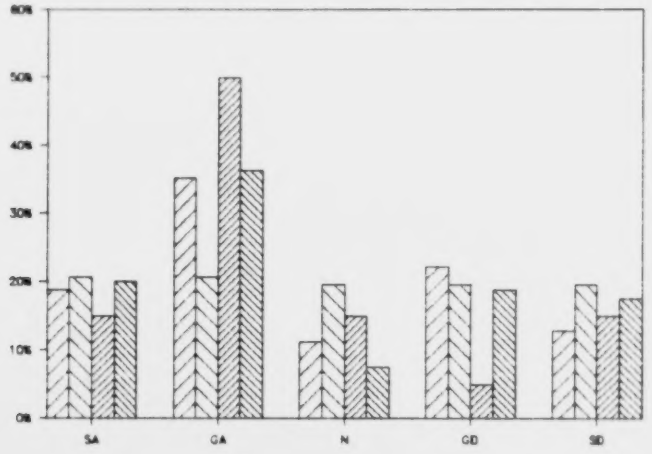
18. DR. ENG. AS PROFESSIONAL DEGREE



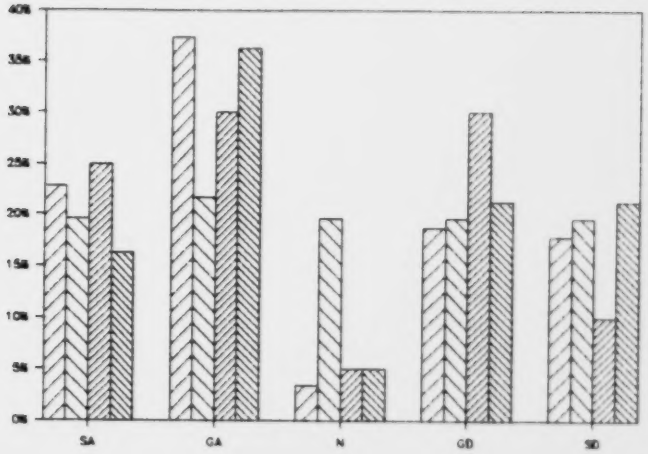
B1. INTERNATIONAL ACCREDITATION



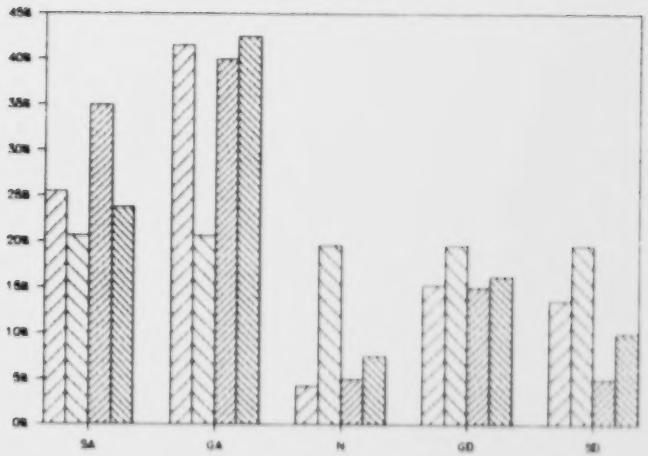
B2. PROFESSIONAL-LEVEL ACCREDITATION



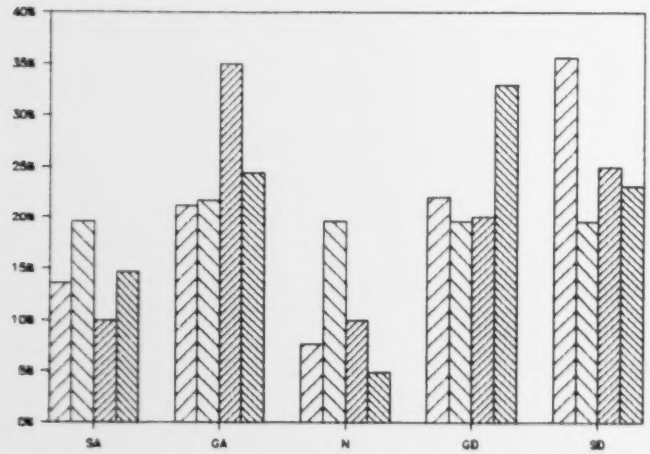
B3. REQUIRE STATISTICS



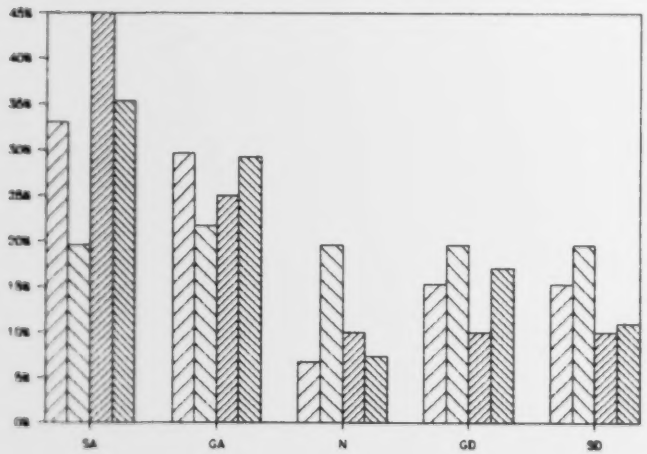
B4. HEALTH & SAFETY



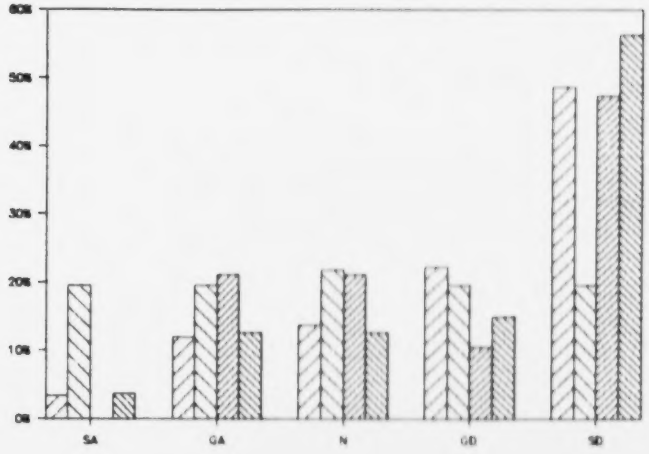
B5. LANGUAGE ADMISSION REQUIREMENT



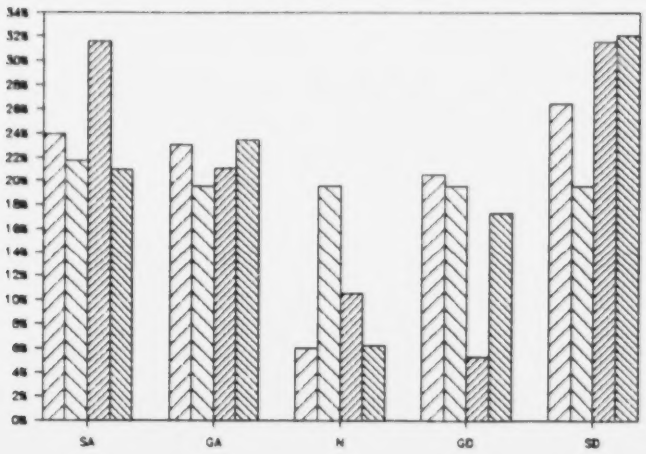
B6. MASTERY OF ENGLISH REQUIREMENT



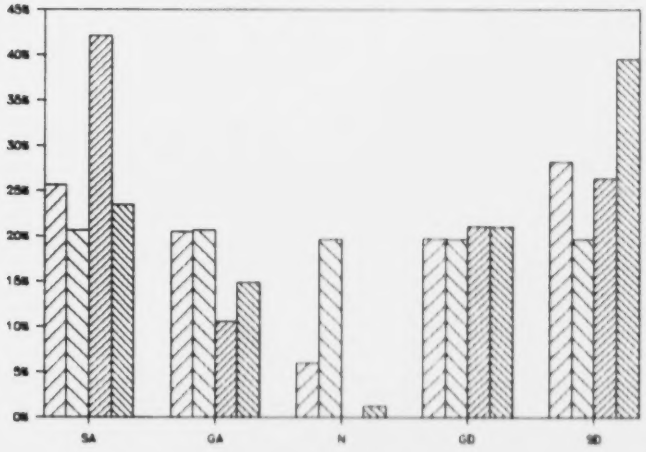
B7. REQUIRE ORIENTAL LANGUAGES



B9. REINSTITUTE DUAL-LEVEL ACCRED.

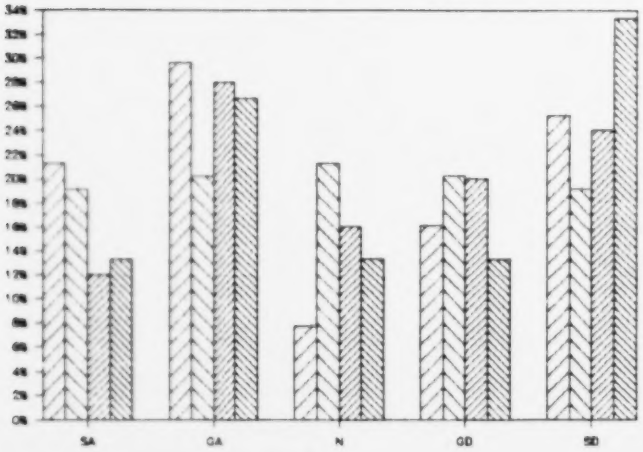


B8. ENCOURAGE 5-YEAR PROGRAM

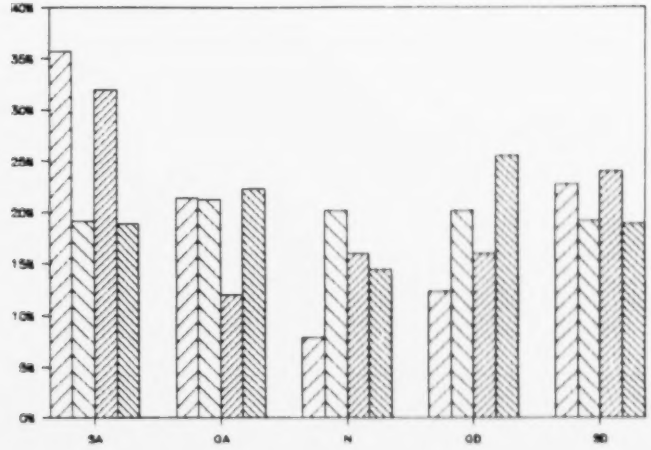


BROAD ACADEMIC ISSUES

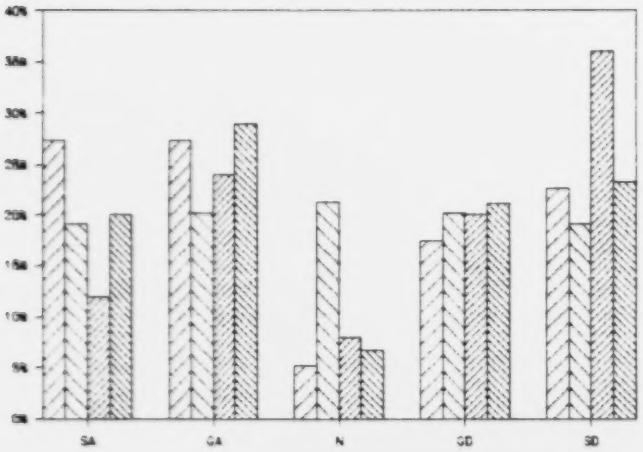
1. LIMITING PROGRAMS



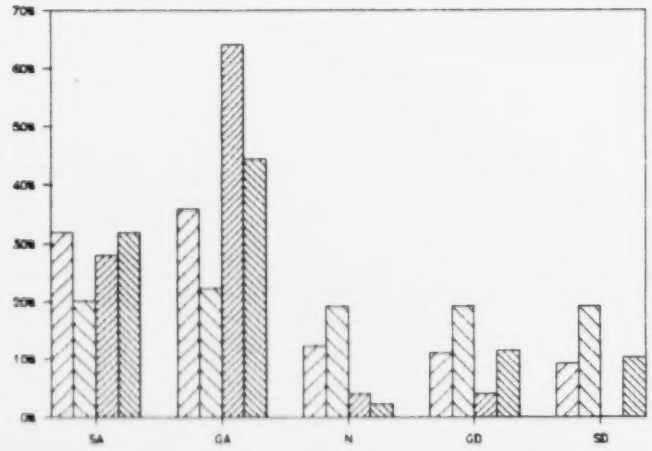
3. MORATORIUM ON NEW SCHOOLS



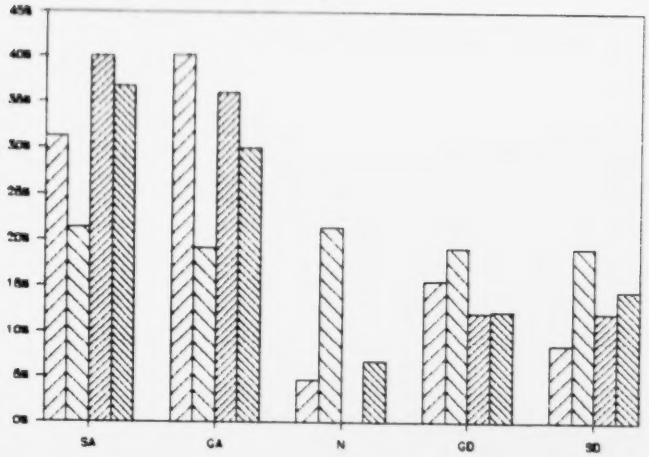
2. MORATORIUM ON PhD PROGRAMS



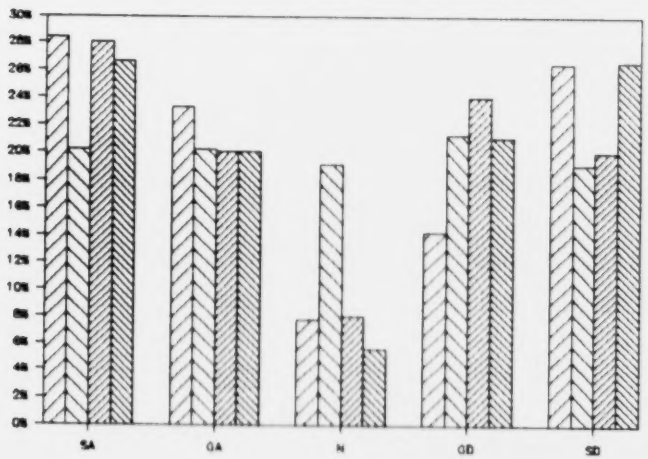
4. FACULTY & LAB REQUIREMENTS



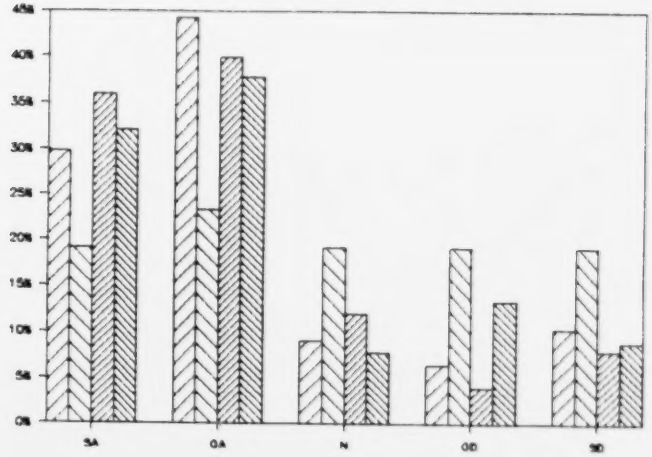
5. ADMISSIONS REQUIREMENT



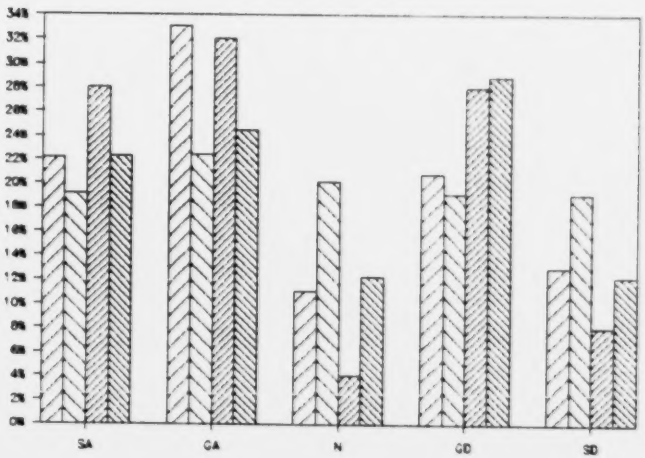
6. REGISTRATION FOR TEACHING



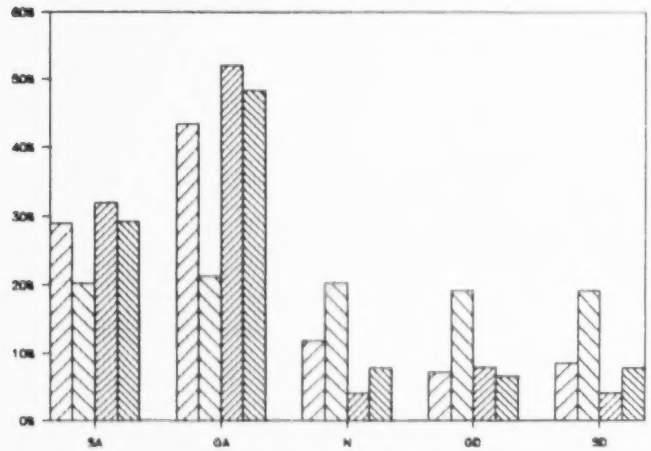
7. ADVISORY COMMITTEES



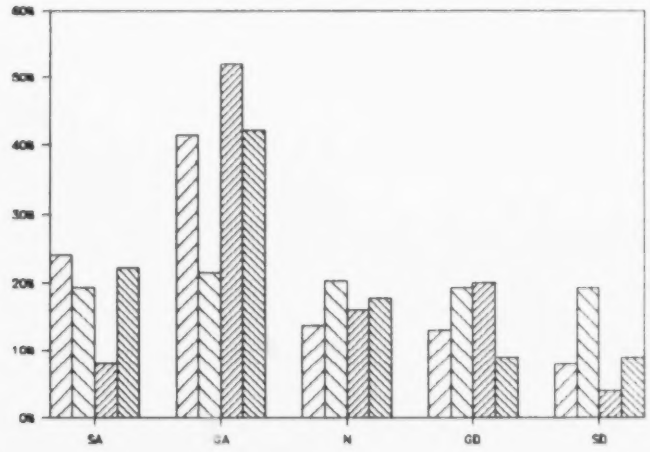
8. QUALITY GOALS



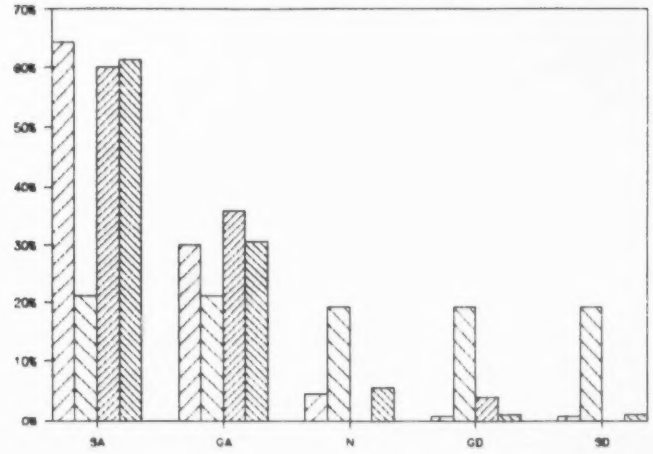
9. UNIVERSITY ENVIRONMENT



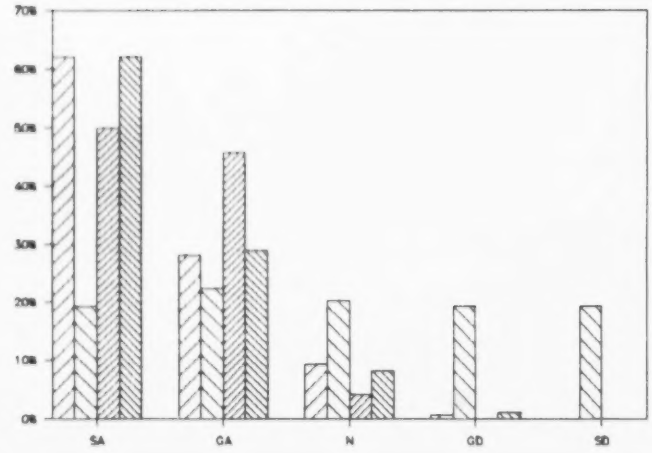
10. CONTINUING EDUCATION



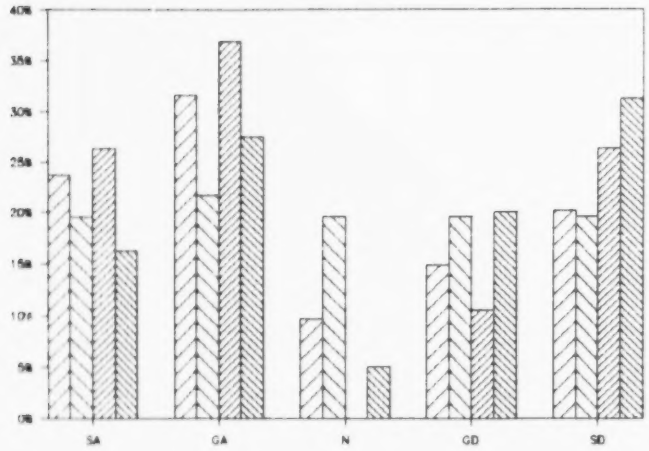
11. COMPETITIVENESS



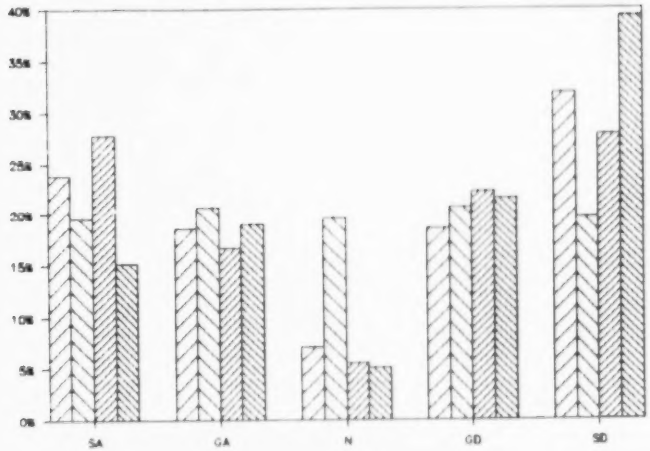
12. NATIONAL SCIENCE BOARD



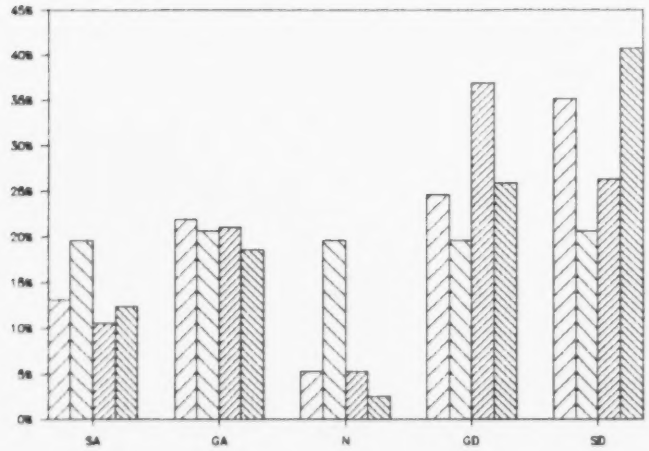
D1. LIMITING PROGRAMS



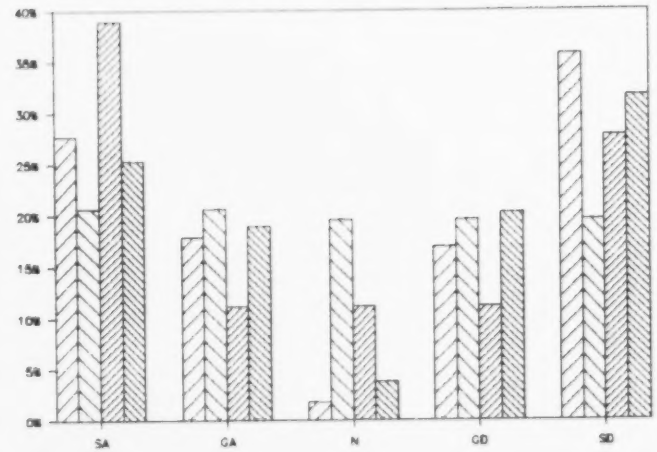
D3. MORATORIUM ON NEW SCHOOLS



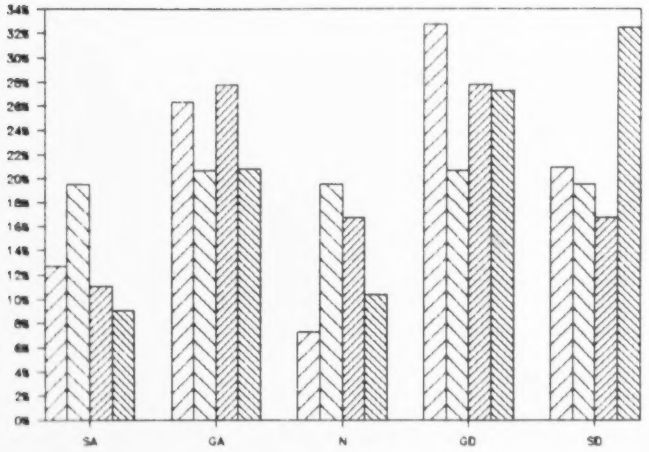
D2. MORATORIUM ON PhD PROGRAMS



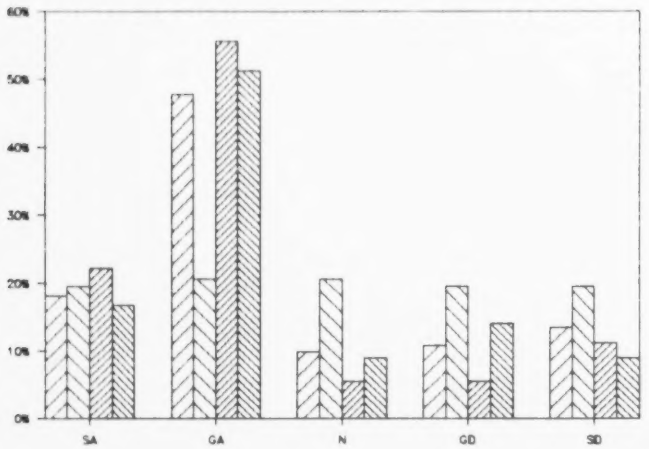
D4. REGISTRATION FOR TEACHING (1st)



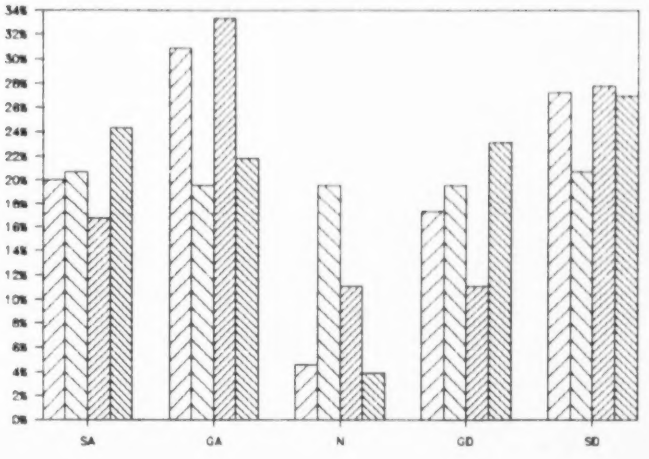
D5. QUALITY GOALS



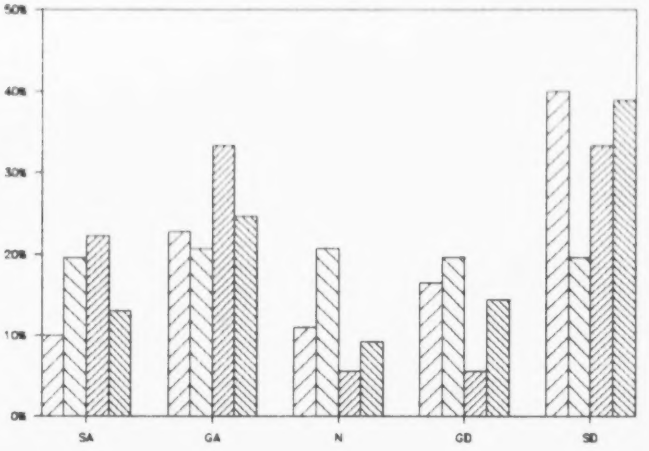
D6. CONTINUING EDUCATION



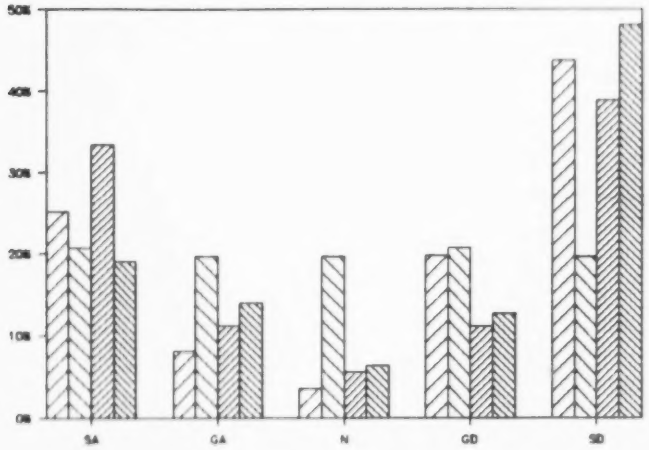
D7. MINORITIES & WOMEN



D8. DR. OF ENG. AS PROFESSIONAL DEGREE



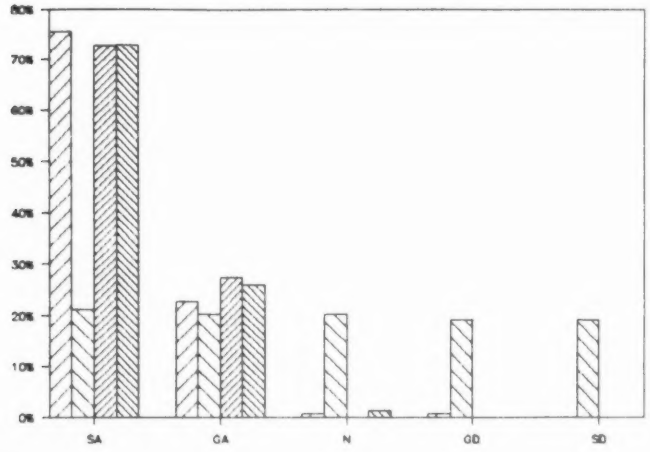
D9. REGISTRATION FOR TEACHING (NCEE)



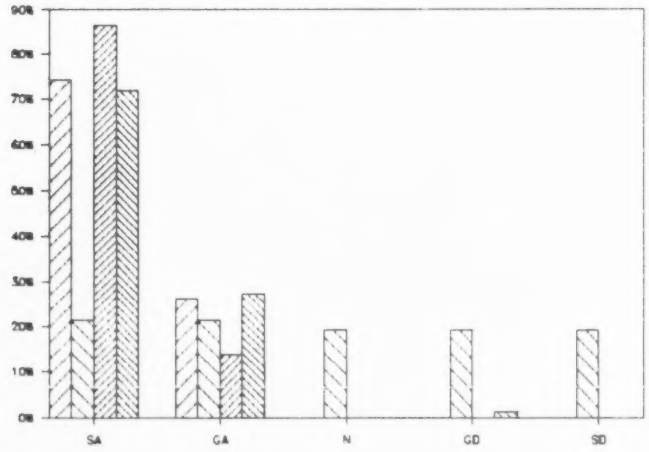
LABORATORY, COMPUTER, AND EDUCATIONAL TECHNOLOGY ISSUES

ROLE OF TECHNOLOGY

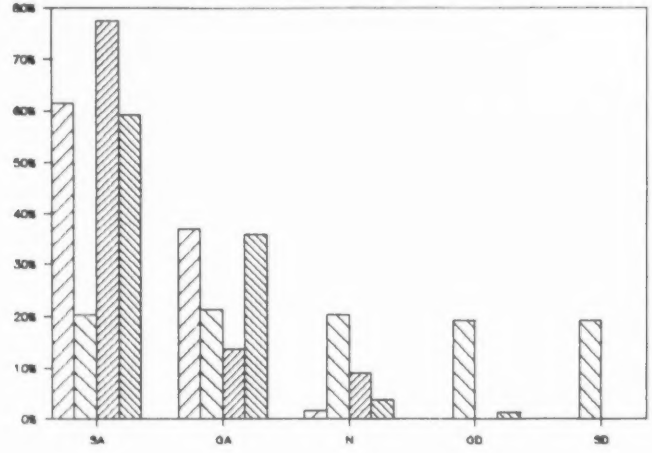
1. FOCUS ON TEACHING



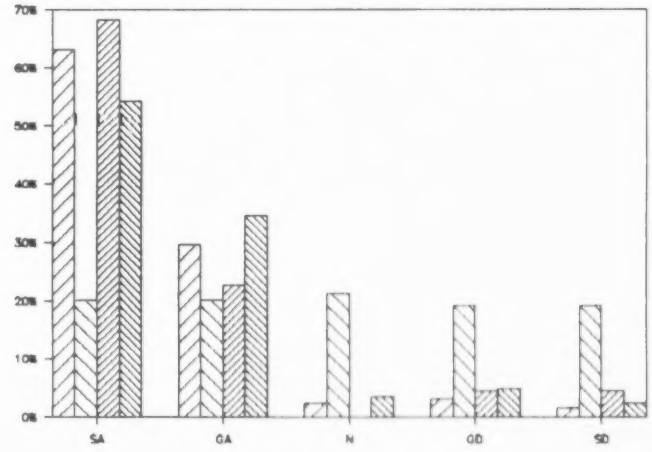
2. LABORATORY EXPERIENCE



3. LIBRARY

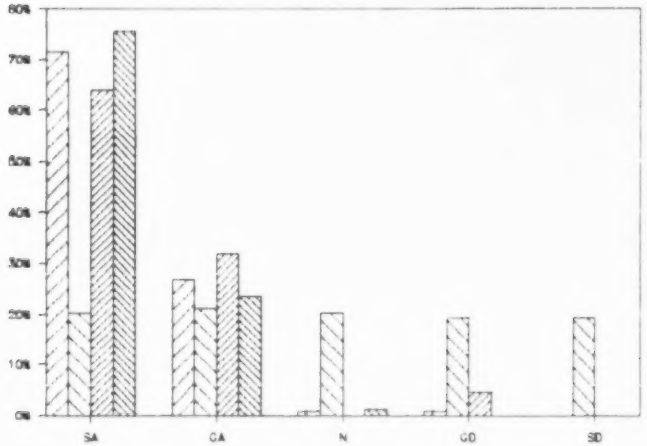


4. LIFE-LONG LEARNING

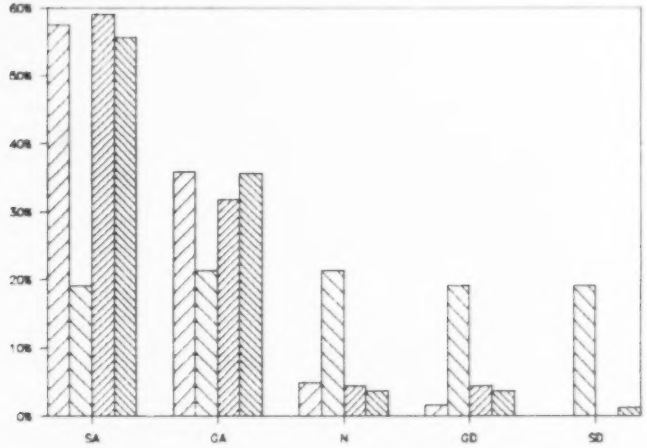


RESOURCE ALLOCATIONS

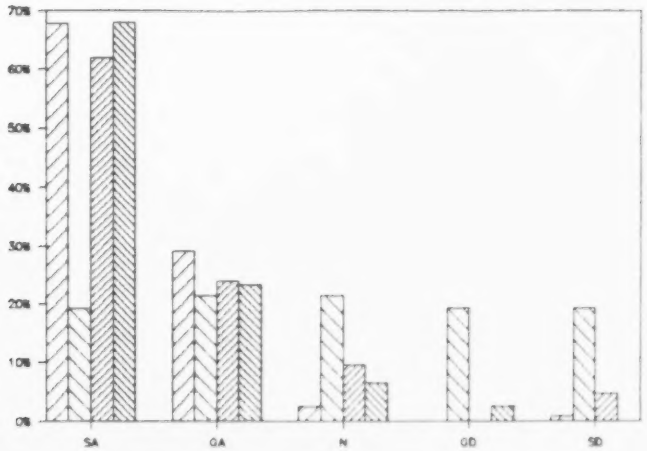
1. INDUSTRY FINANCIAL SUPPORT



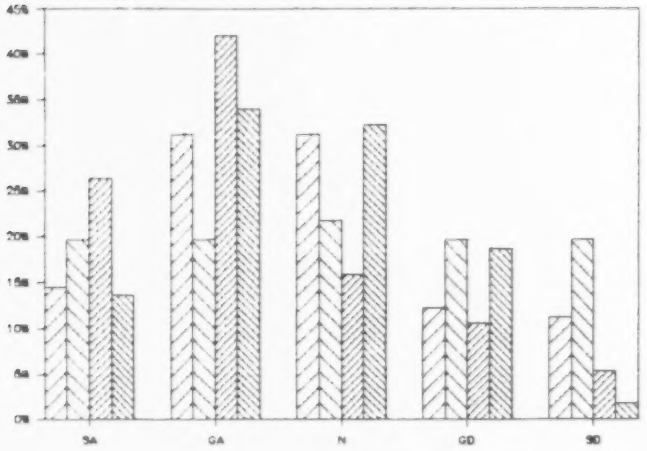
3. DONATED EQUIPMENT



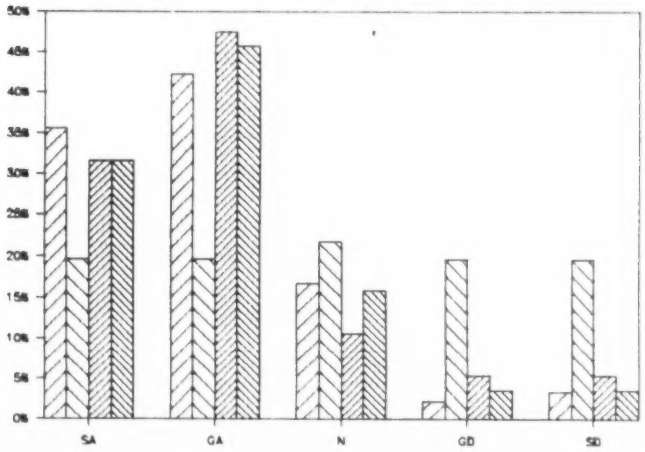
2. COMPUTER MAINTENANCE



4. UTILIZE REGIONAL LABORATORIES

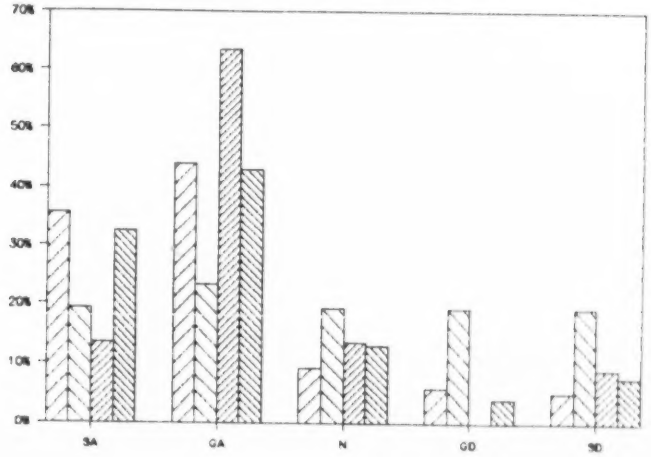


5. TECHNICAL STAFF TRAINED BY INDUSTRY

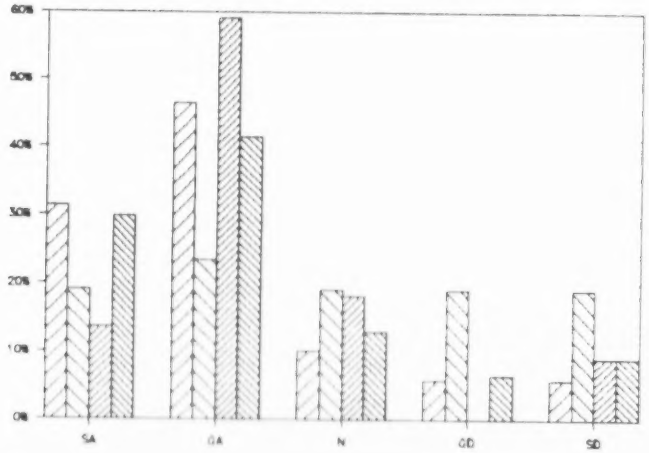


ACCREDITATION CRITERIA

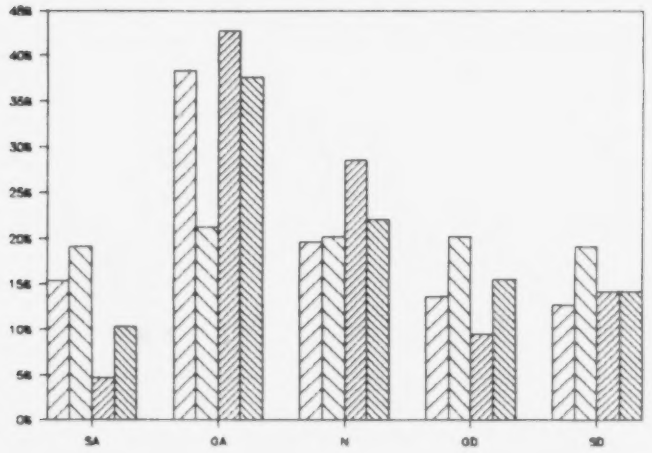
1. LABORATORY REQUIREMENT



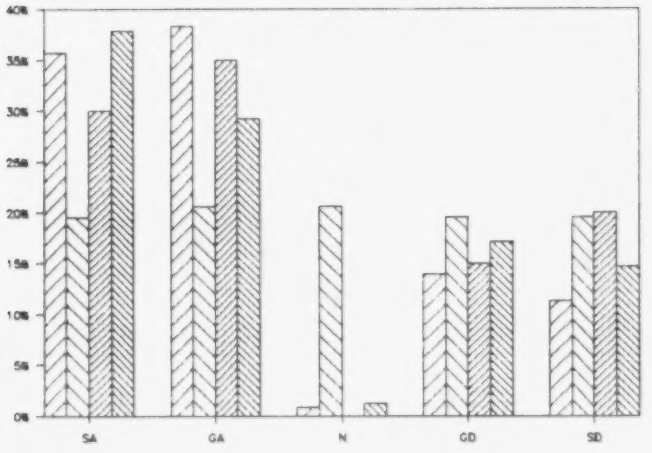
2. COMPUTER REQUIREMENT



3. "STRAWMAN" CRITERIA

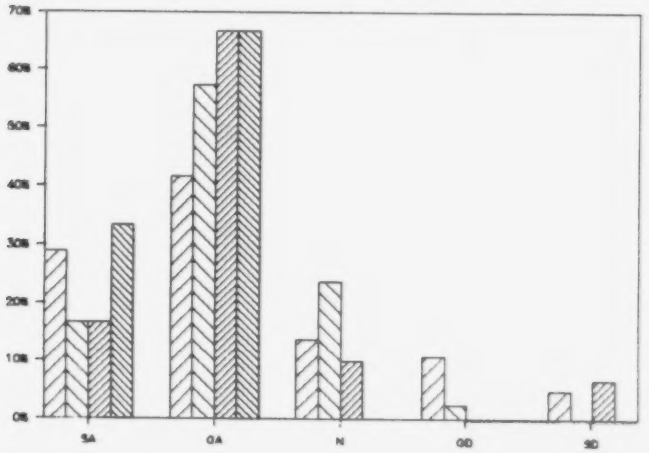


C1. SPECIFIC CRITERIA

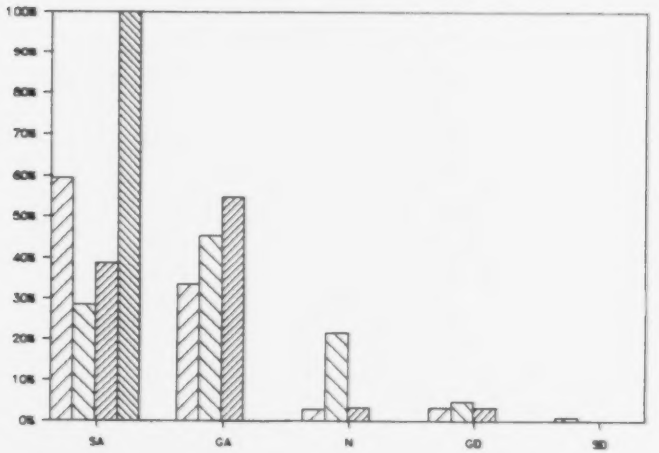


FACULTY RESOLUTIONS

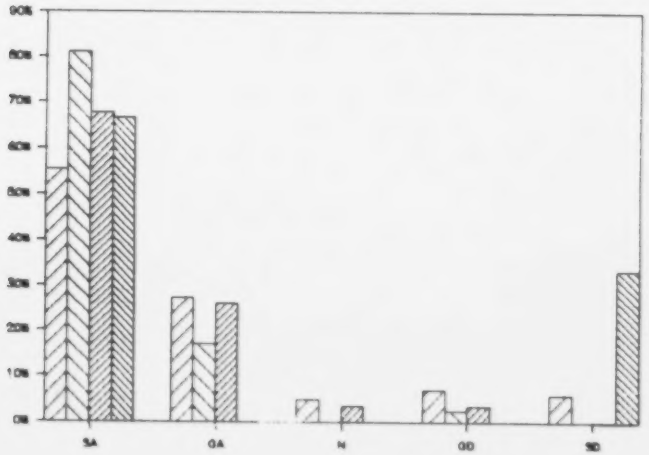
1. GRADUATE PROGRAM ATTRACTIVENESS



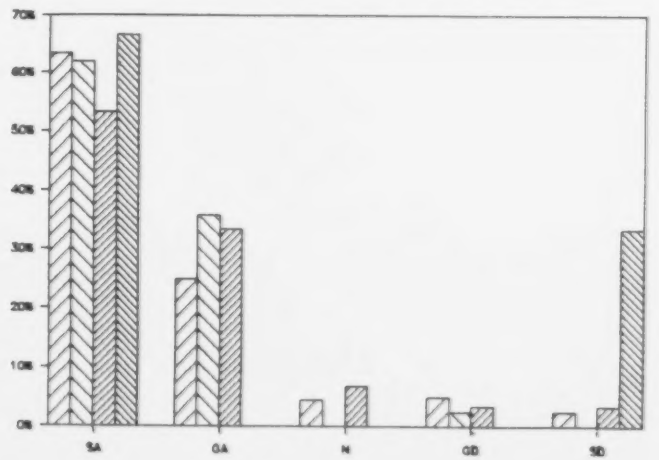
2. GRADUATE SUPPORT

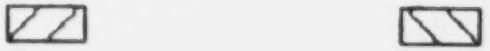


3. PROFICIENCY IN ENGLISH

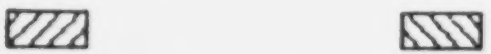


4. THE TEACHING FUNCTION



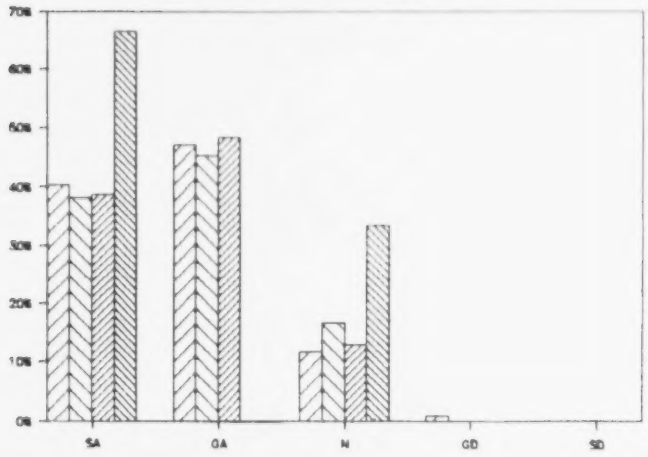


Engineering Education Engineering Practice

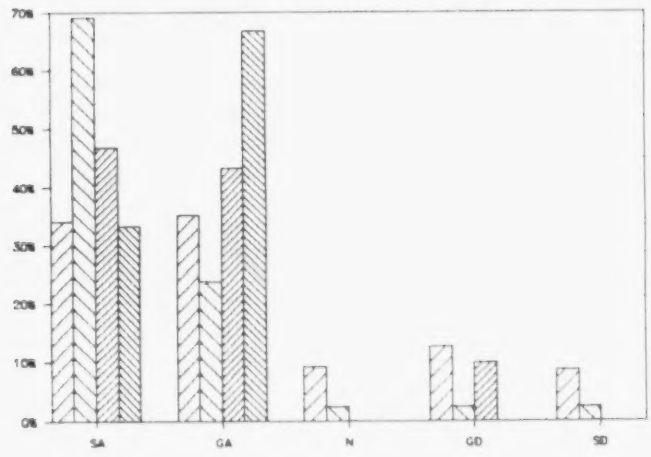


Engineering Policy Non–Engineering

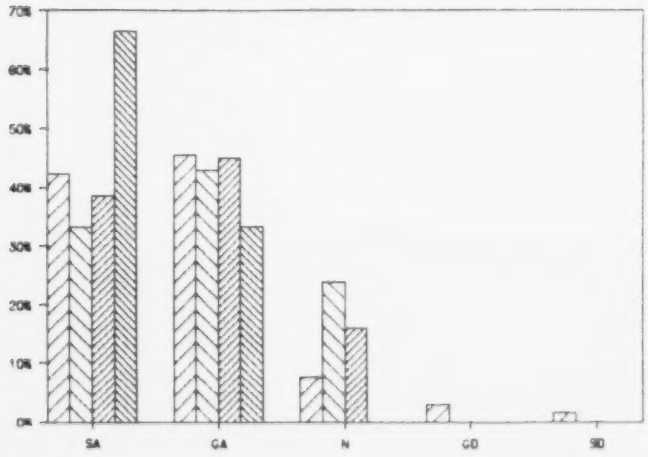
5. TEACHING WORKSHOPS



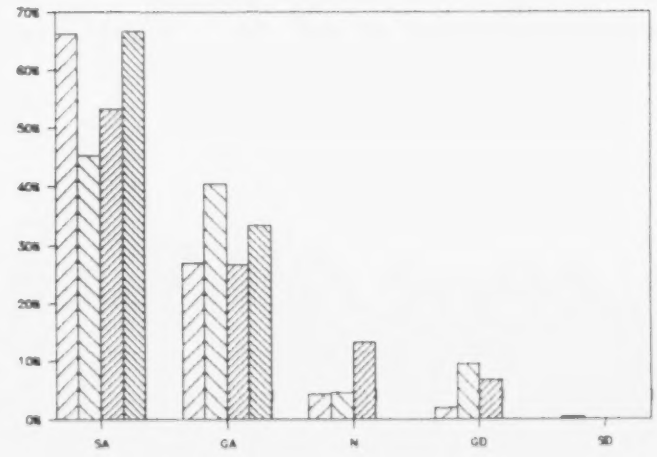
6. ENGINEERING PRACTICE



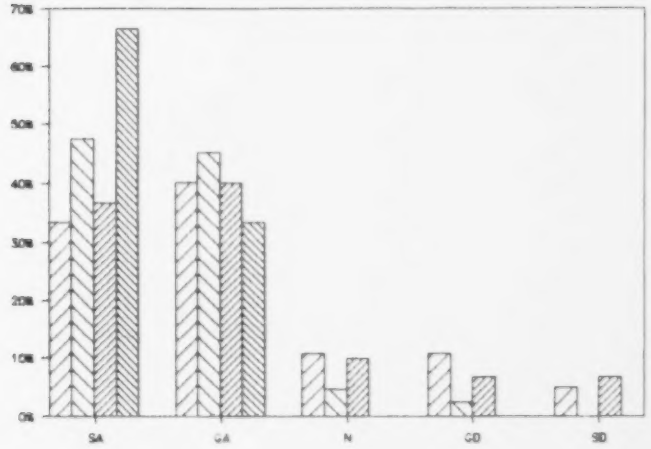
7. BALANCED DEPARTMENTS



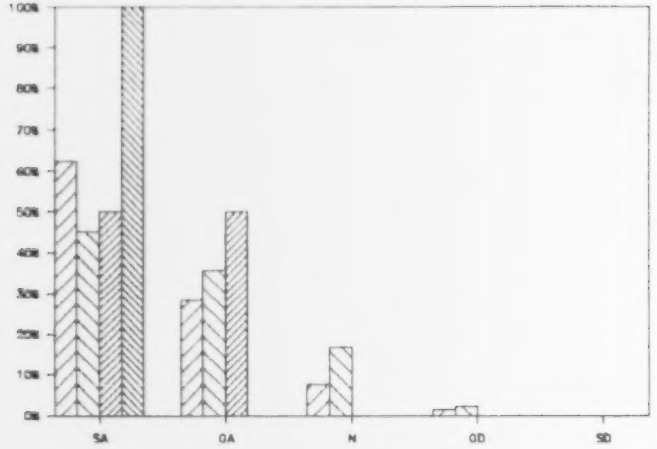
8. FACULTY CAREER ATTRACTIVENESS



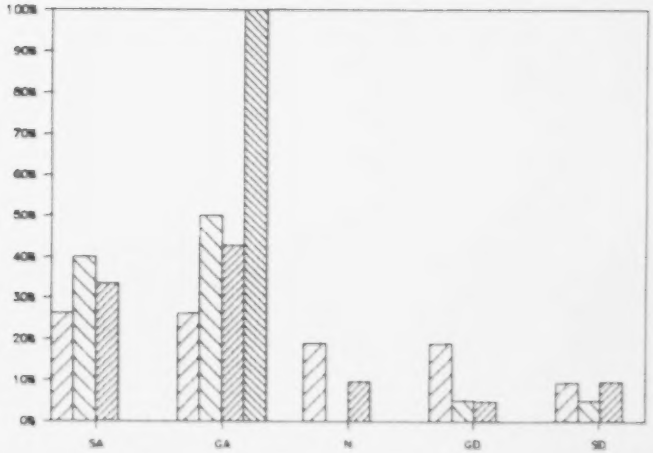
9. PROFESSIONAL COMPETENCE



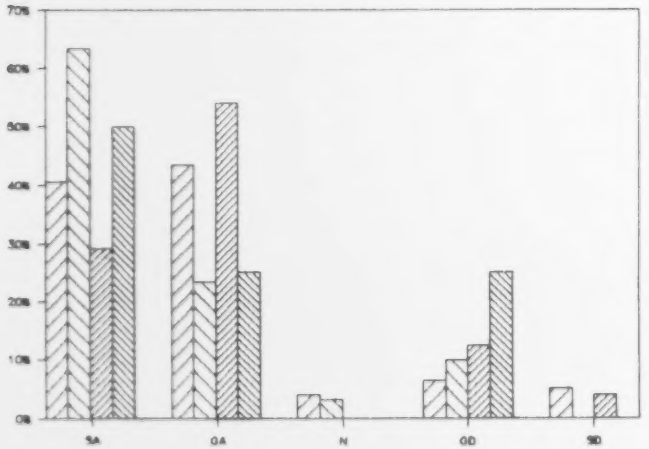
10. INTERACTION WITH INDUSTRY



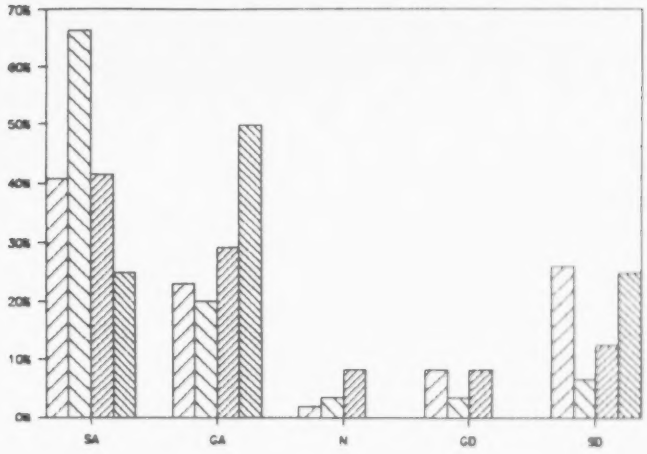
11. UTILIZE FACULTY W/O DOCTORATES



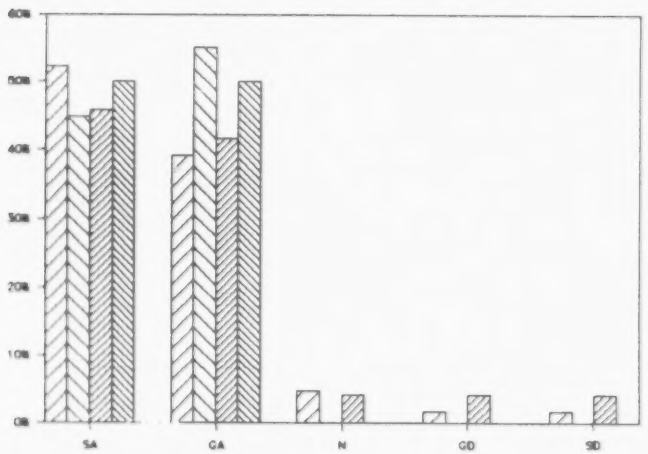
A1. GRADUATE PROGRAM ATTRACTIVENESS



A2. PROFICIENCY IN ENGLISH

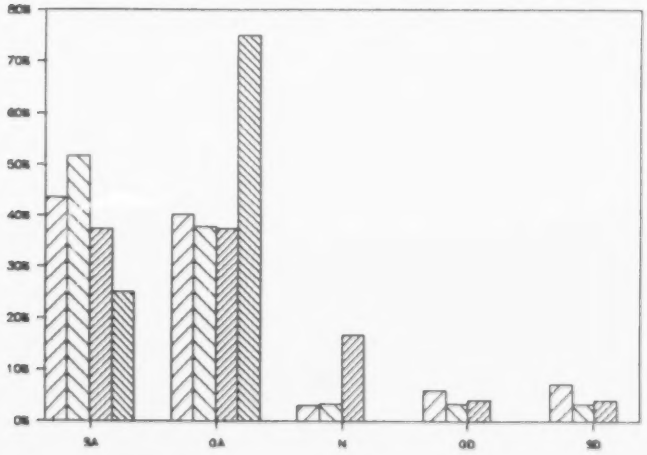


A3. PROFESSIONAL COMPETENCE

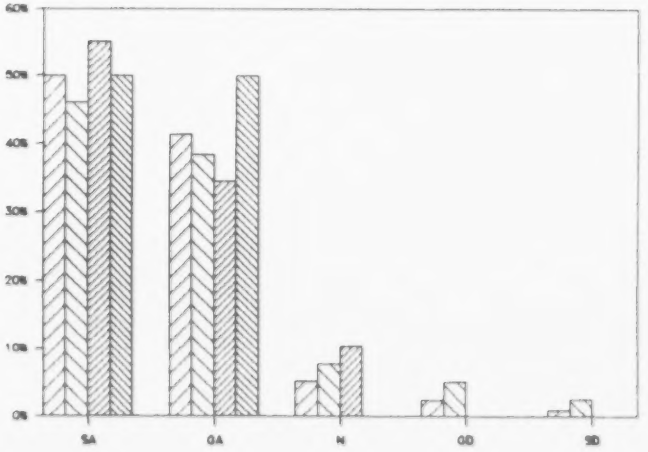


CURRICULUM ISSUES

A4. UTILIZE FACULTY W/O DOCTORATES



1. COMPUTER USE



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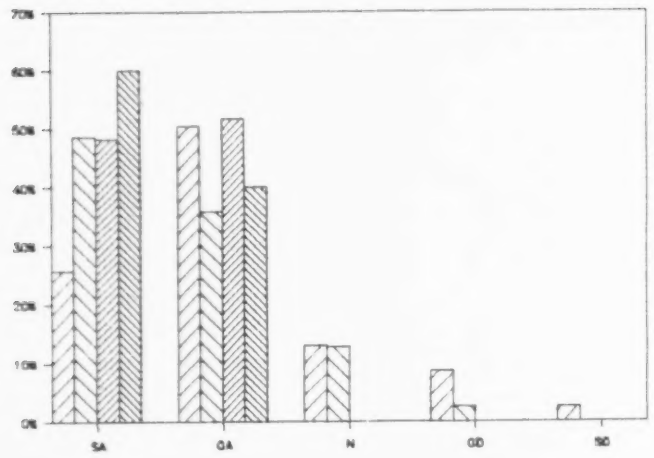
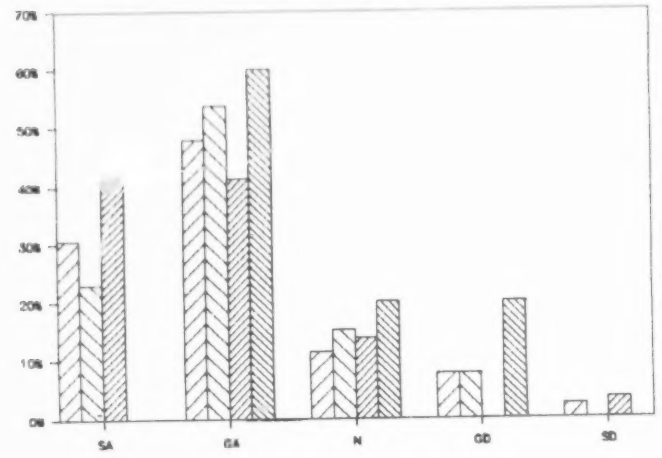
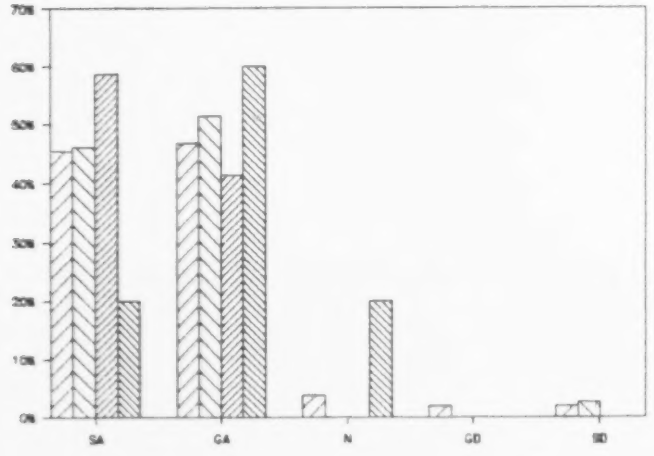
2. MANUFACTURING & CONSTRUCTION



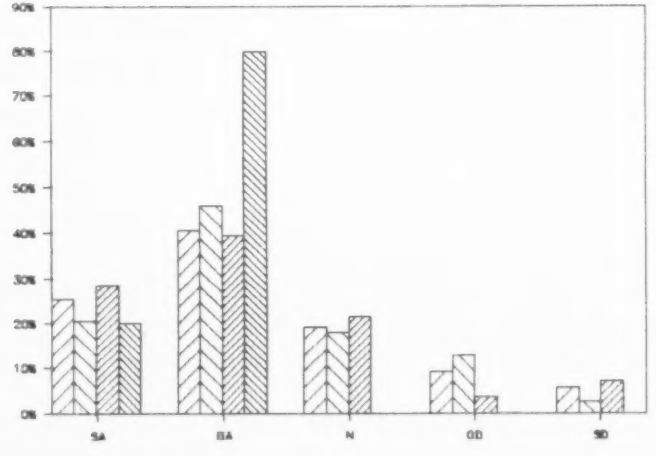
3. BASIC SCIENCE REQUIREMENT



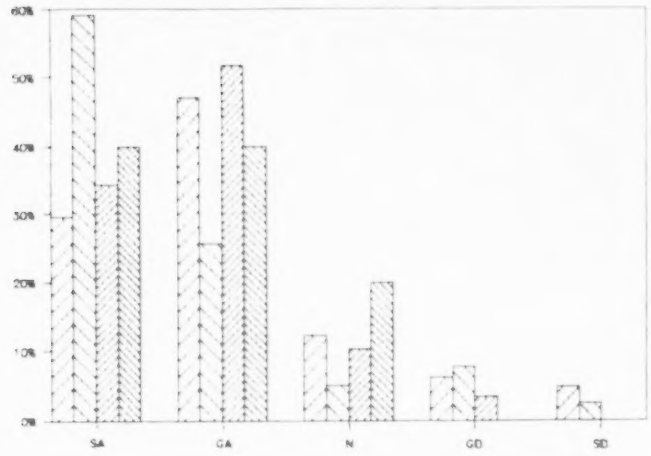
4. MATHEMATICS REQUIREMENT



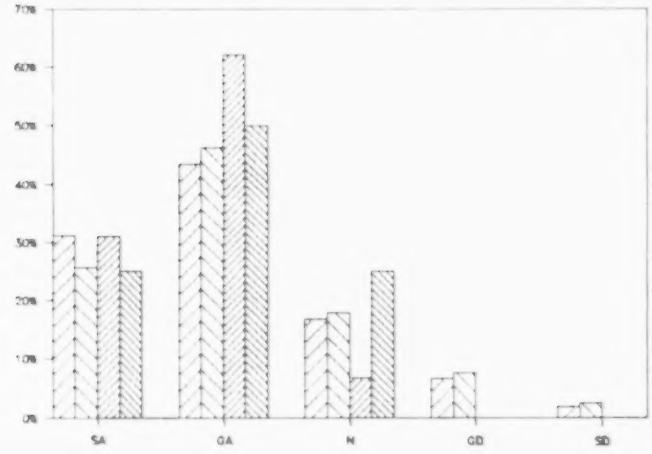
5. THE GLOBAL ECONOMY



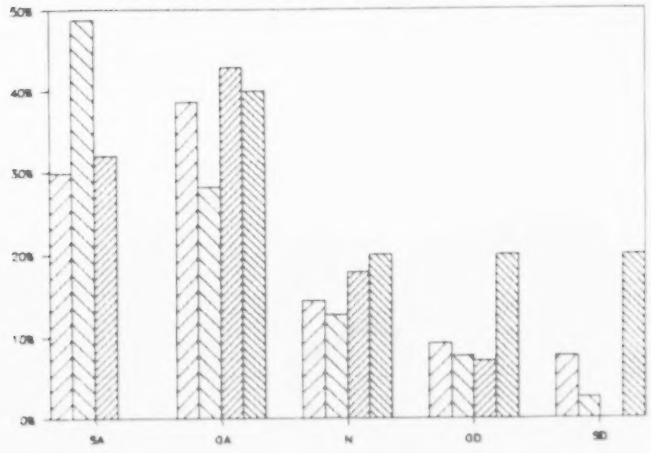
6. THE INDUSTRIAL ENVIRONMENT



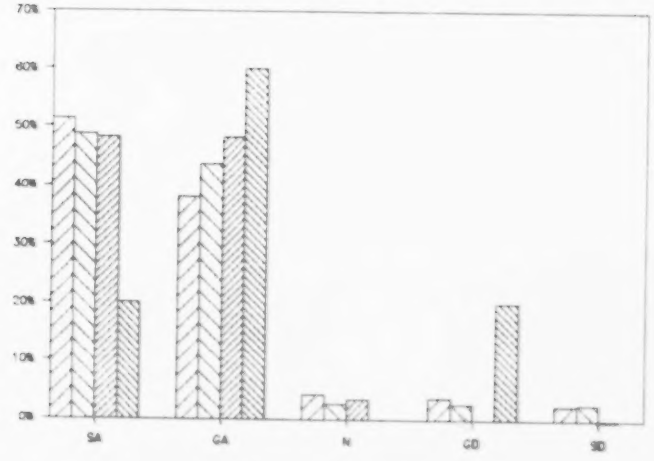
7. ENGINEERING SCIENCE CRITERIA



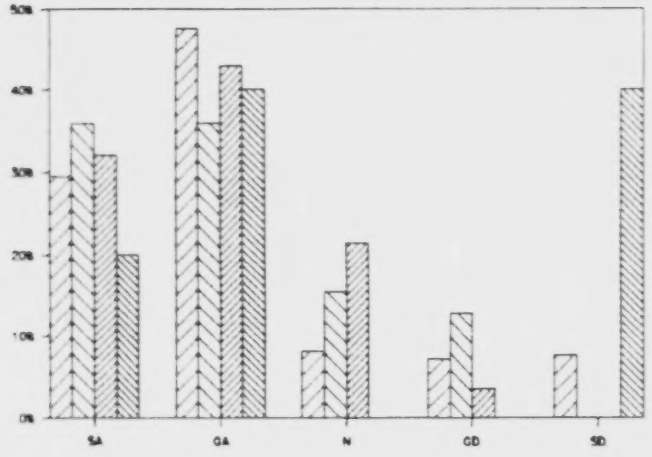
8. BASIC EDUCATION REQUIREMENT



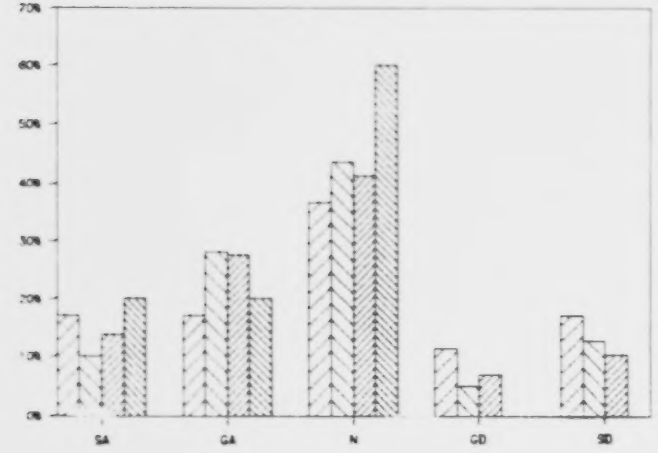
9. ENGINEERING DESIGN CRITERIA



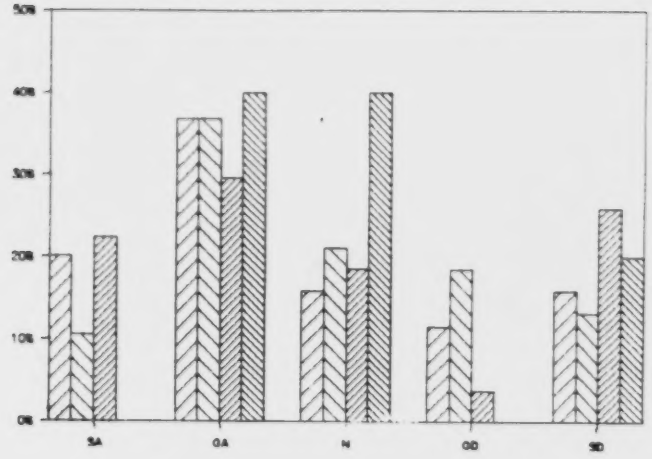
10. LIBERAL ARTS & HUMANITIES



11. INTERNATIONAL ACCREDITATION

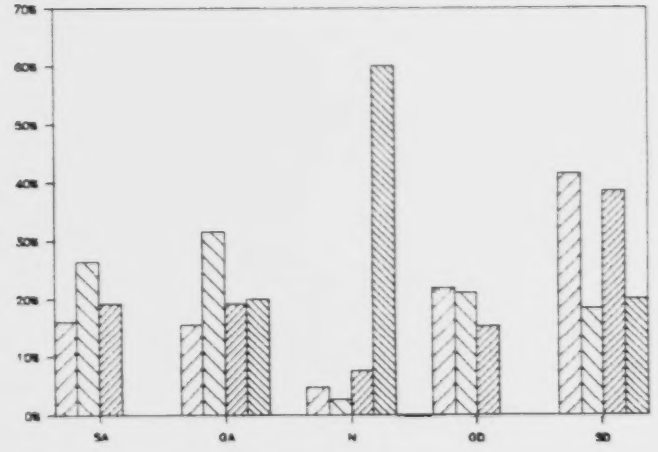


12. PROFESSIONAL-LEVEL ACCREDITATION

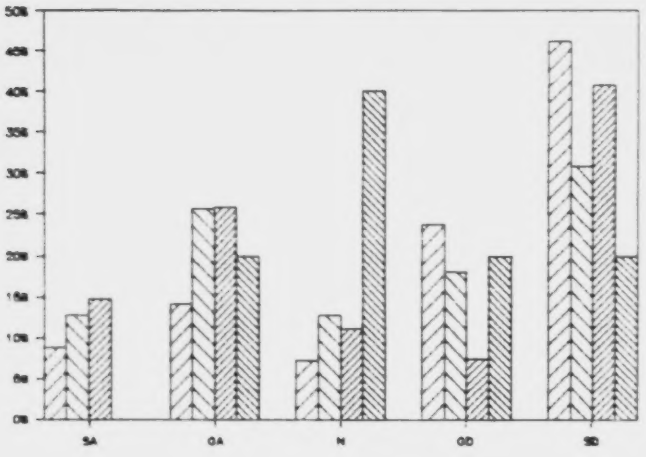


13. ACADEMIC PROGRAM LENGTH

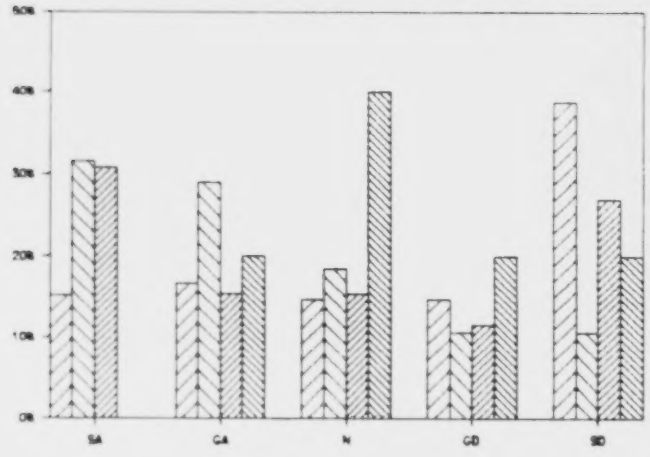
13. I. ENCOURAGE 5-YEAR PROGRAM



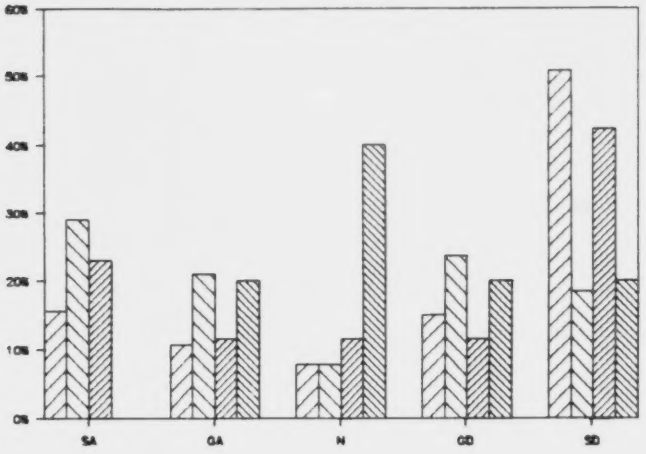
13. II. REDUCE TECHNICAL CONTENT



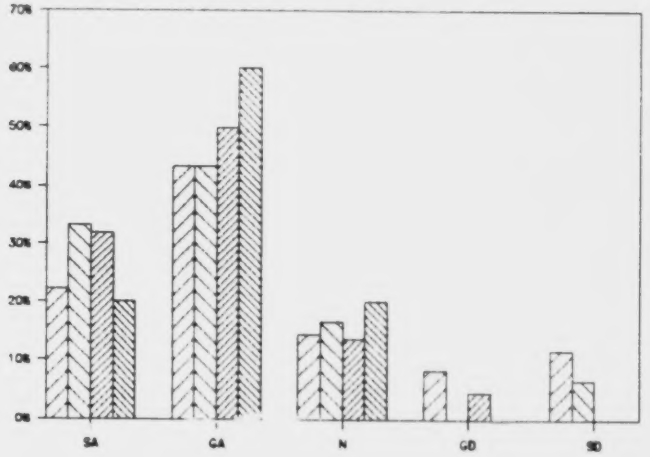
13. III. REINSTITUTE DUAL LEVEL



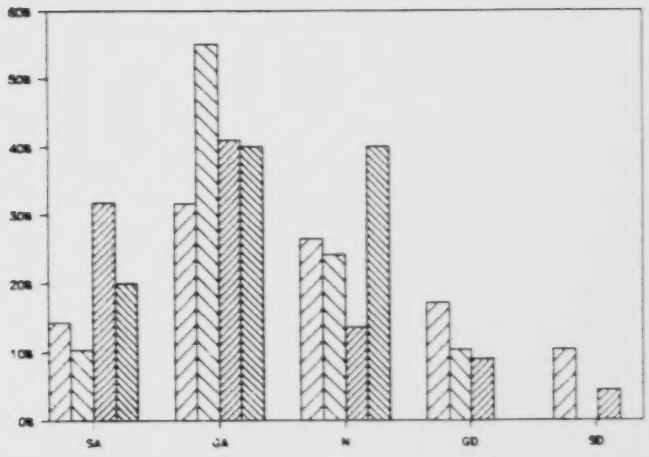
13. IV. PRESCRIBE 5-YEARS BY 1995



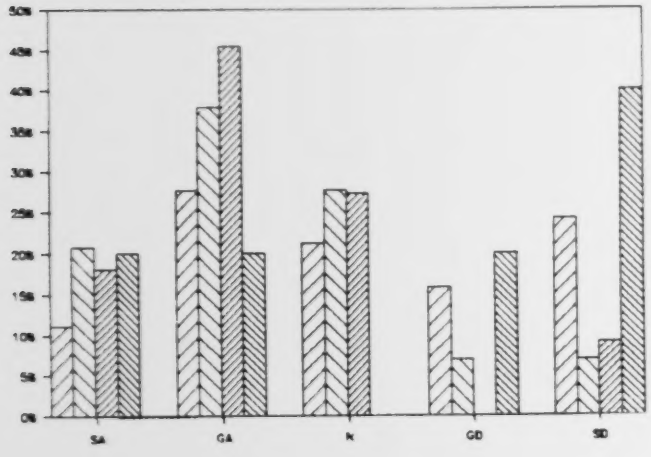
14. REQUIRE STATISTICS



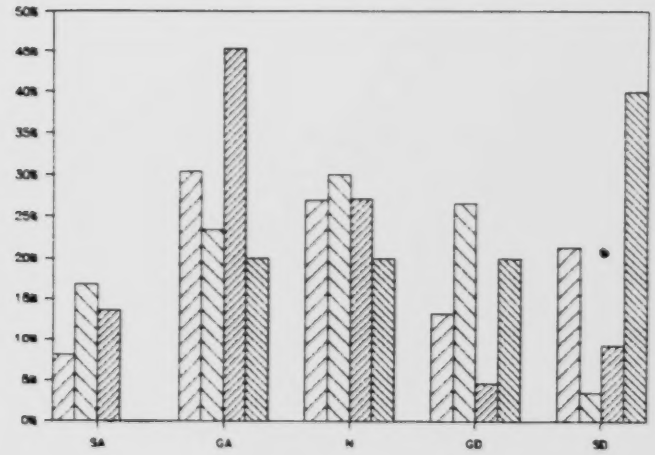
15. HEALTH & SAFETY



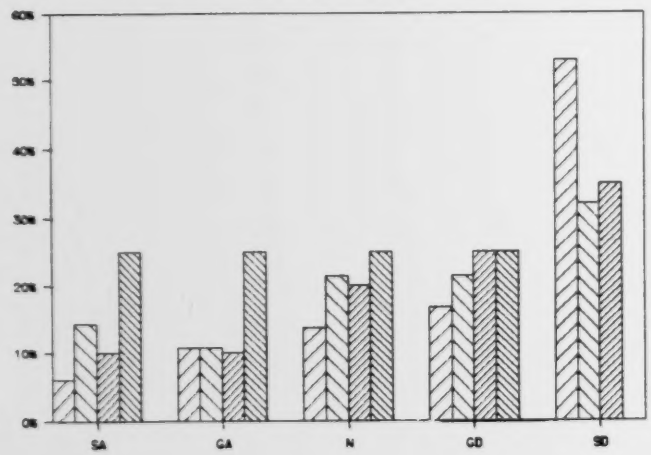
16. LANGUAGE ADMISSION REQUIREMENT



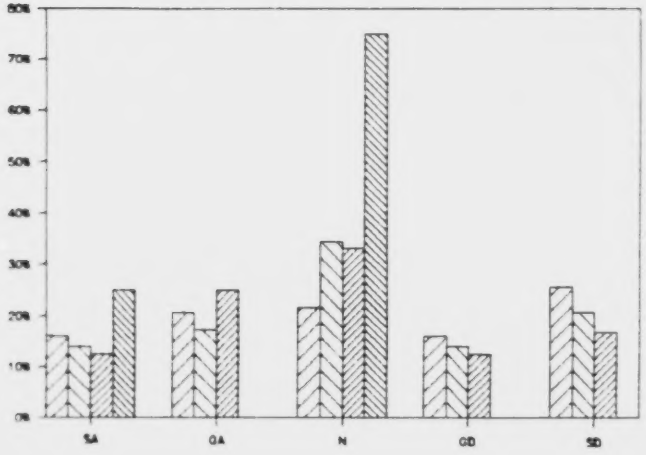
17. REQUIRE ORIENTAL LANGUAGES



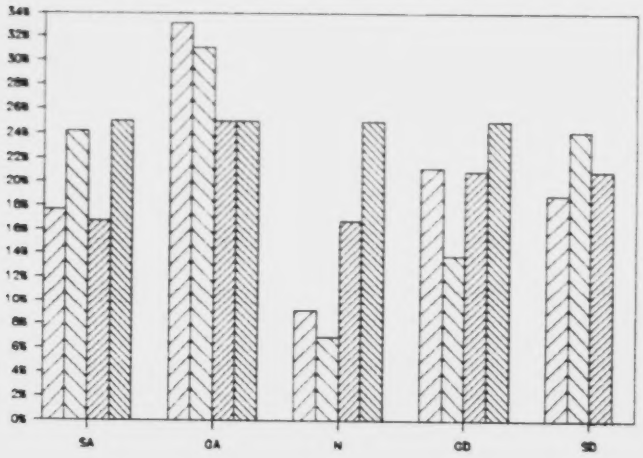
18. DR. ENG. AS PROFESSIONAL DEGREE



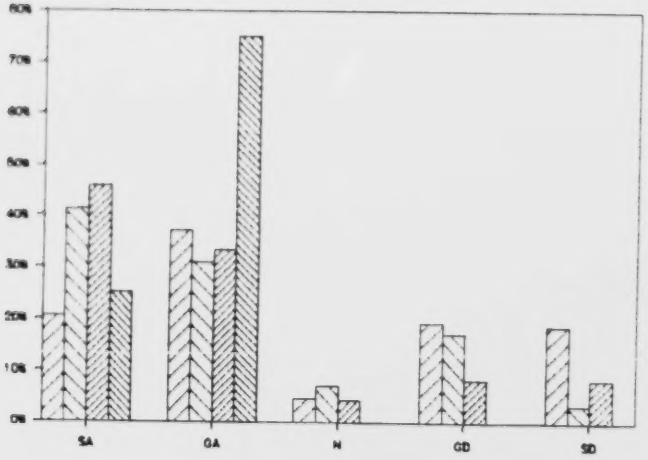
B1. INTERNATIONAL ACCREDITATION



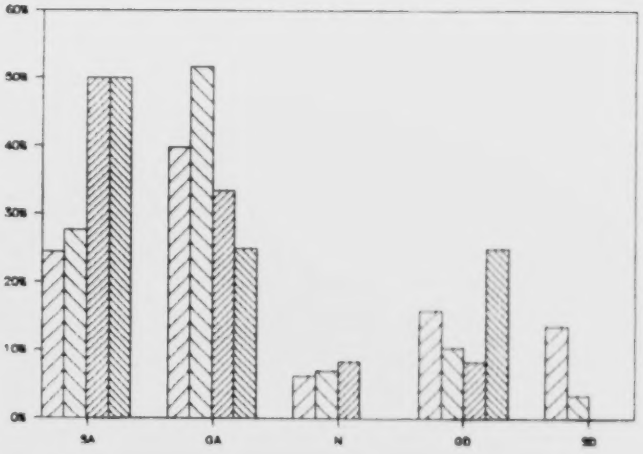
B2. PROFESSIONAL-LEVEL ACCREDITATION



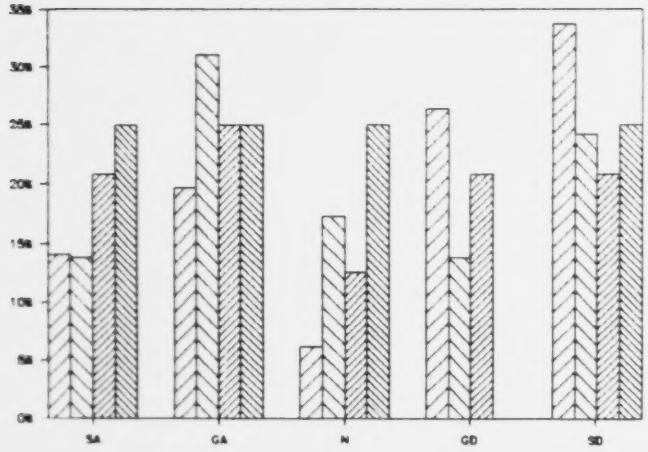
B3. REQUIRE STATISTICS



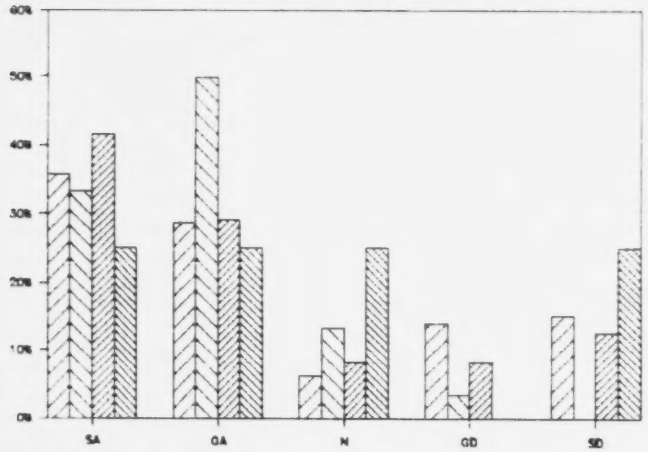
B4. HEALTH & SAFETY



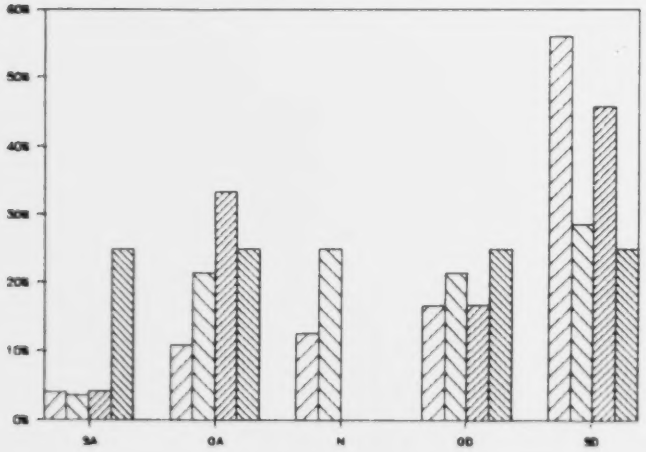
B5. LANGUAGE ADMISSION REQUIREMENT



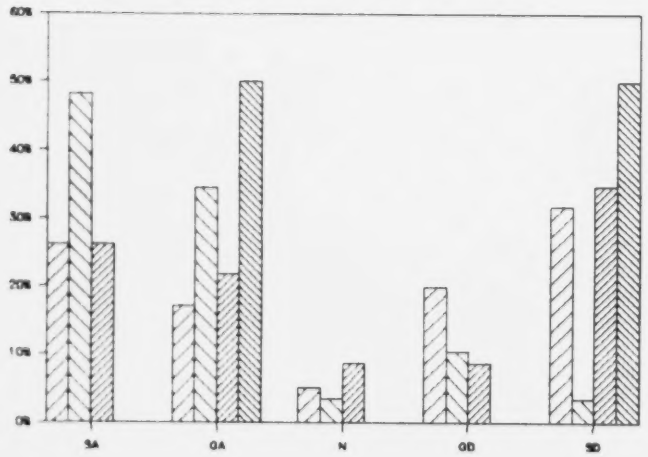
B6. MASTERY OF ENGLISH REQUIREMENT



B7. REQUIRE ORIENTAL LANGUAGES

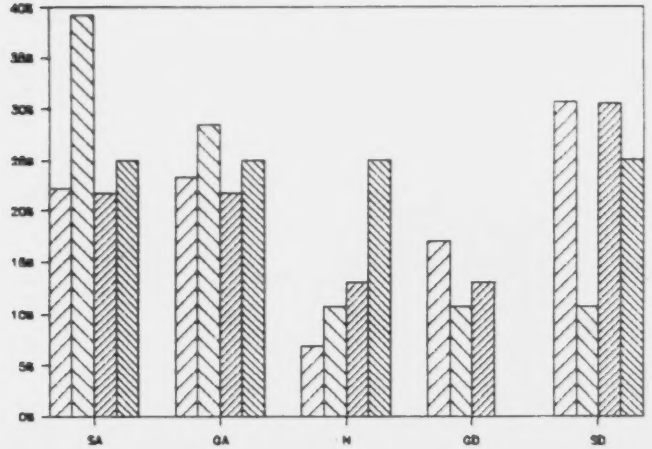


B8. ENCOURAGE 5-YEAR PROGRAM

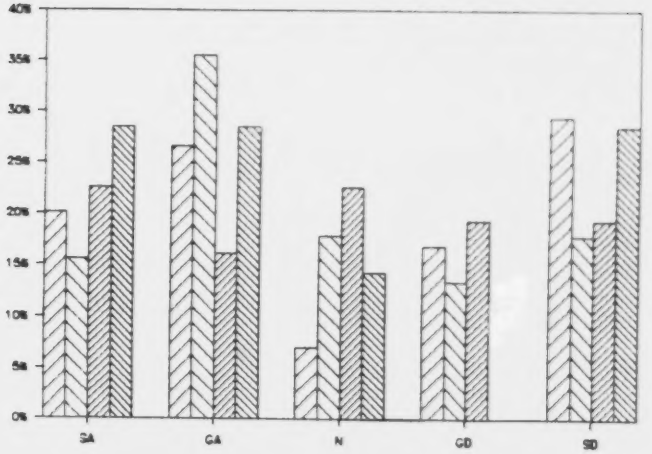


BROAD ACADEMIC ISSUES

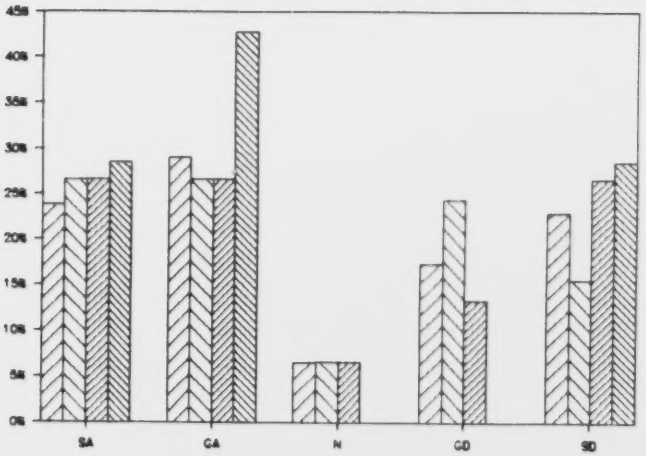
B9. REINTITUTE DUAL LEVEL ACCRED.



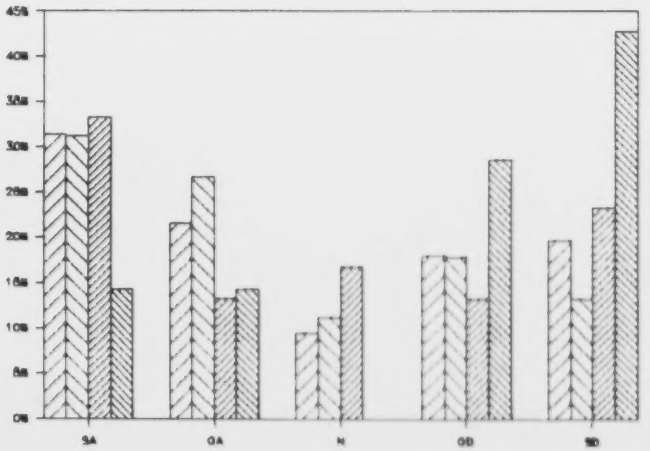
1. LIMITING PROGRAMS



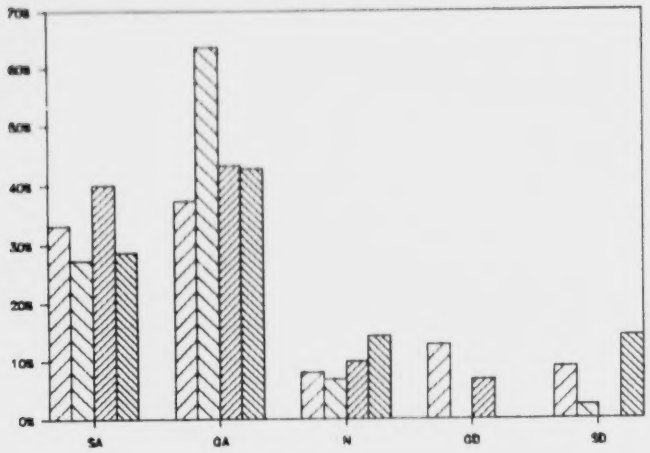
2. MORATORIUM ON PhD PROGRAMS



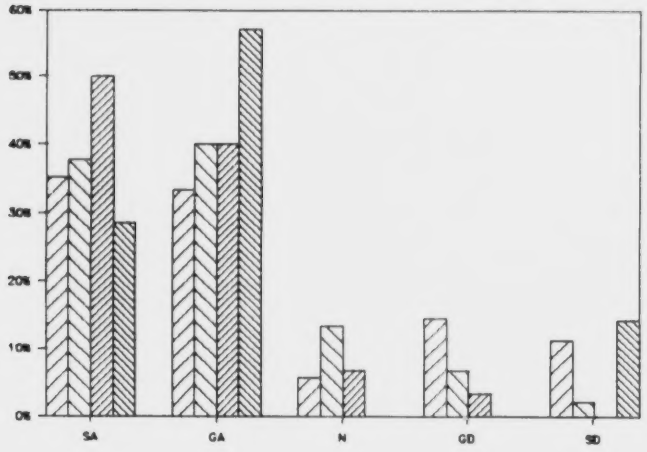
3. MORATORIUM ON NEW SCHOOLS



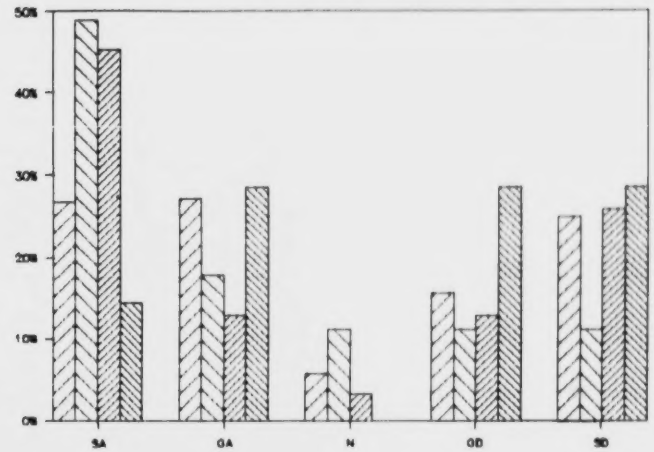
4. FACULTY & LAB REQUIREMENTS



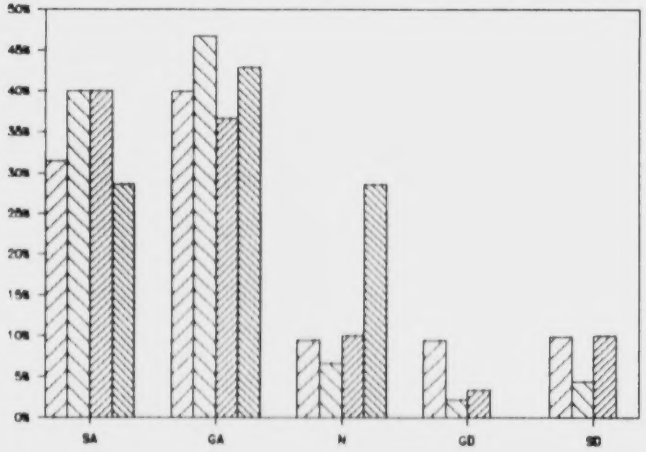
5. ADMISSIONS REQUIREMENTS



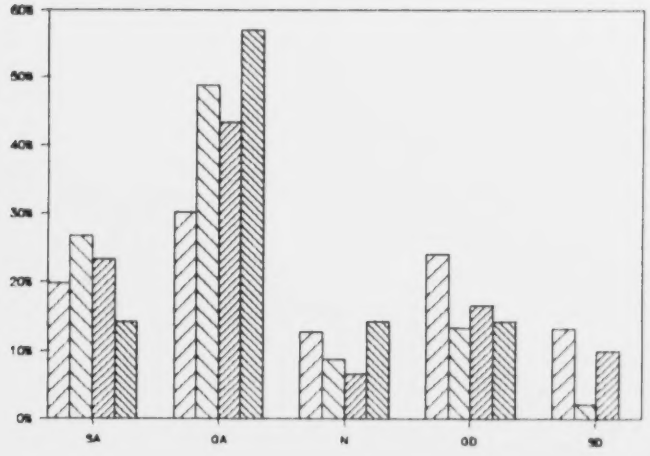
6. REGISTRATION FOR TEACHING



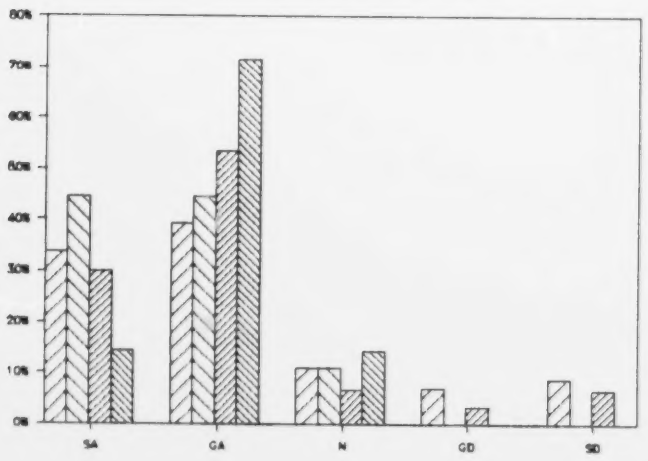
7. ADVISORY COMMITTEES



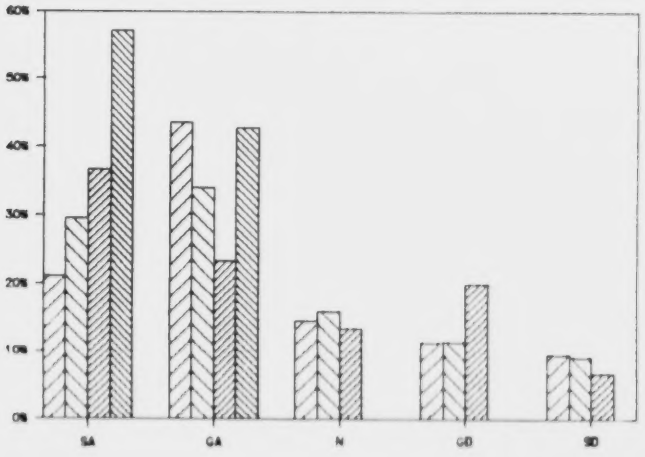
8. QUALITY GOALS



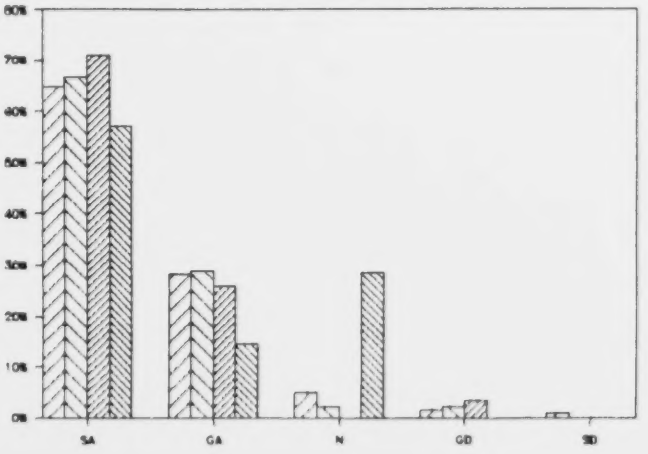
9. UNIVERSITY ENVIRONMENT



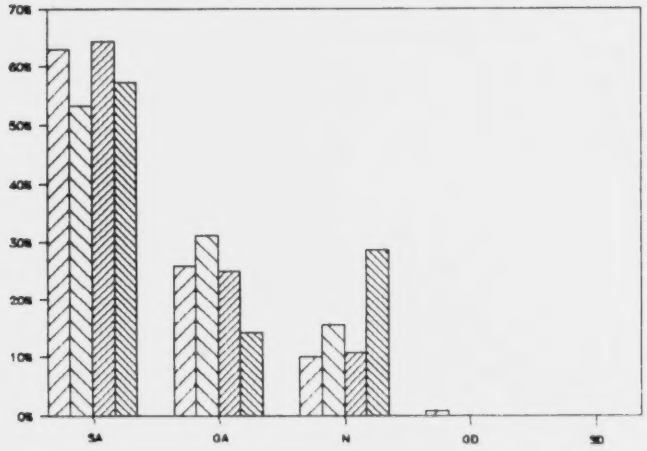
10. CONTINUING EDUCATION



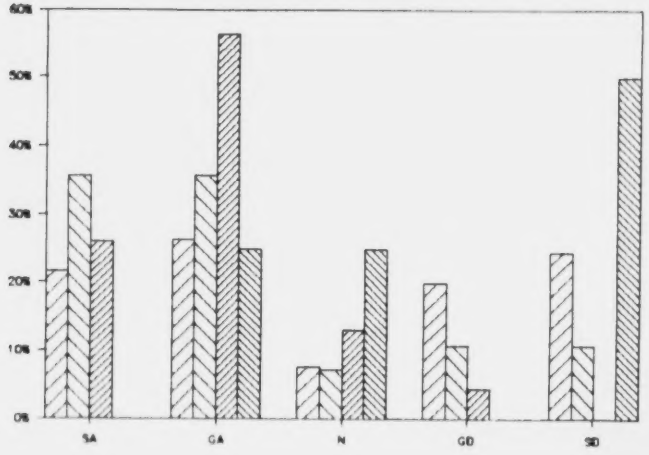
11. COMPETITIVENESS



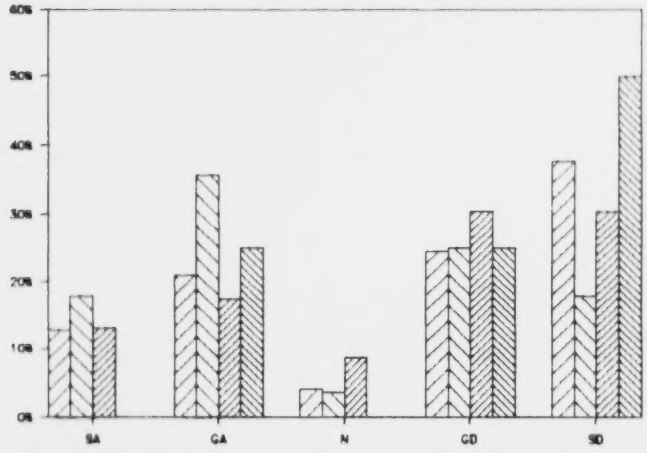
12. NATIONAL SCIENCE BOARD



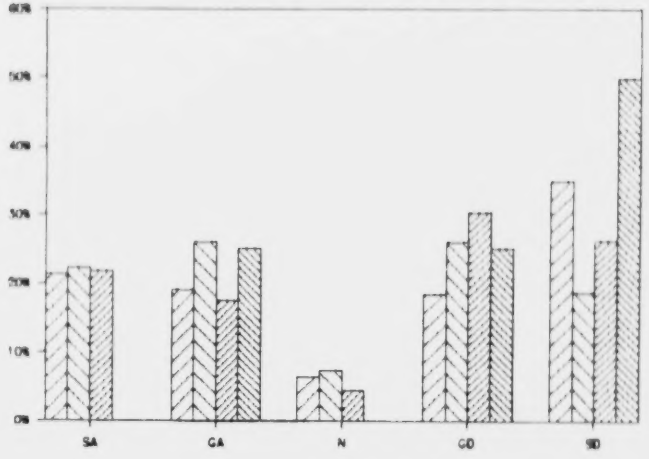
D1. LIMITING PROGRAMS



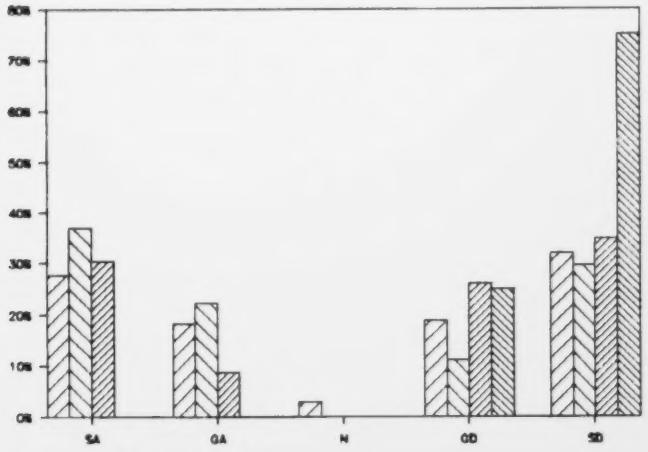
D2. MORATORIUM ON PhD PROGRAMS



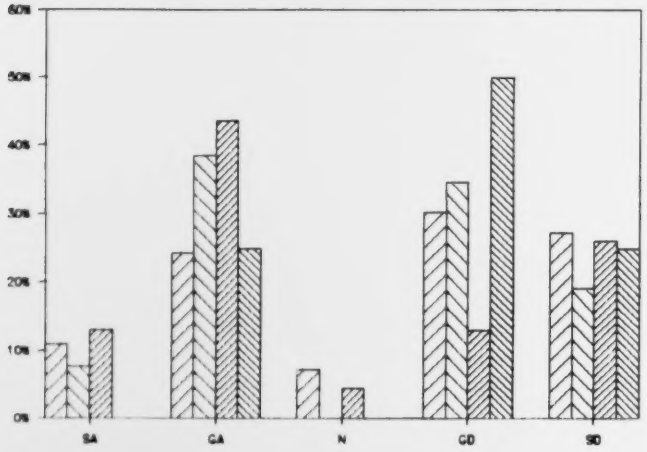
D3. MORATORIUM ON NEW SCHOOLS



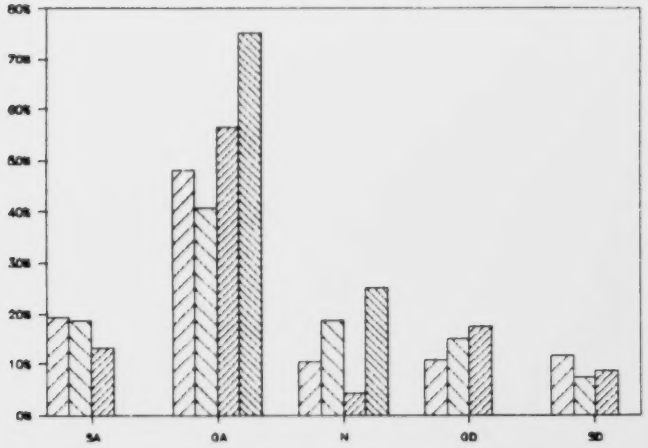
D4. REGISTRATION FOR TEACHING (1st)



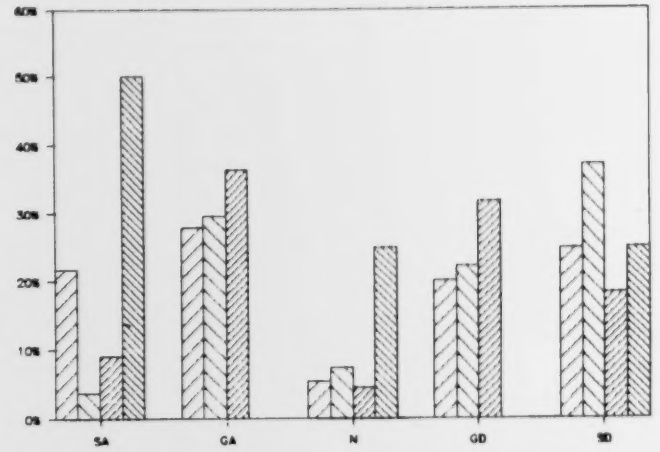
D5. QUALITY GOALS



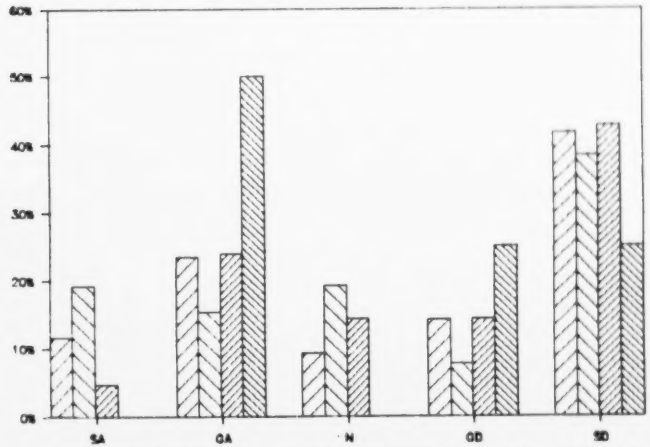
D6. CONTINUING EDUCATION



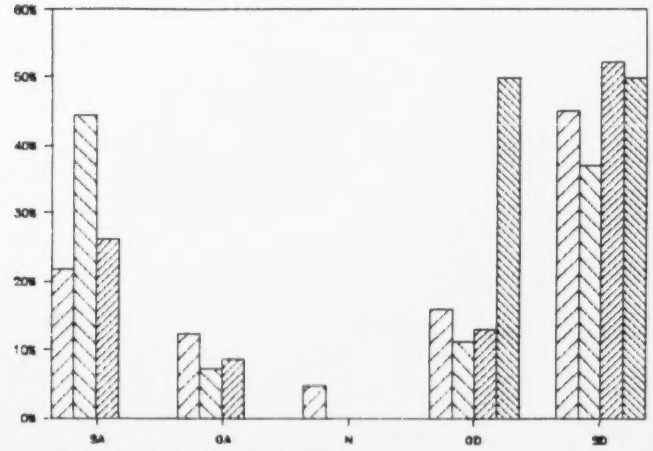
D7. MINORITIES & WOMEN



D8. DR. OF ENG. AS PROFESSIONAL DEGREE



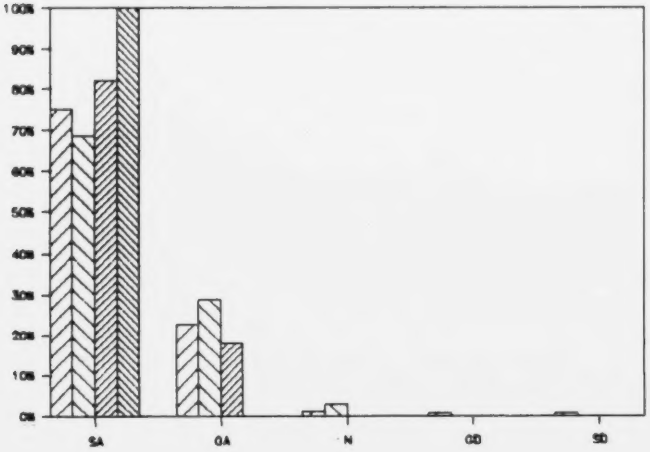
D9. REGISTRATION FOR TEACHING (NCEE)



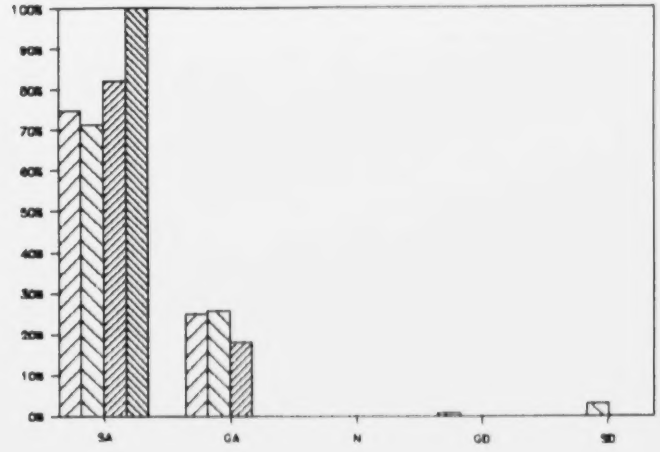
LABORATORY, COMPUTER, AND EDUCATIONAL TECHNOLOGY ISSUES

ROLE OF TECHNOLOGY

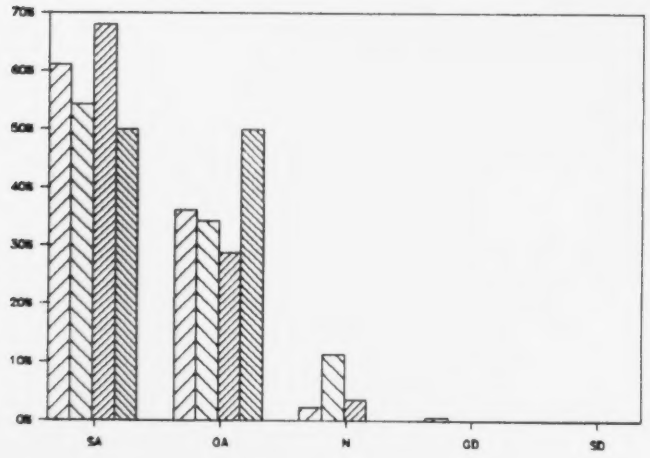
A. FOCUS ON TEACHING



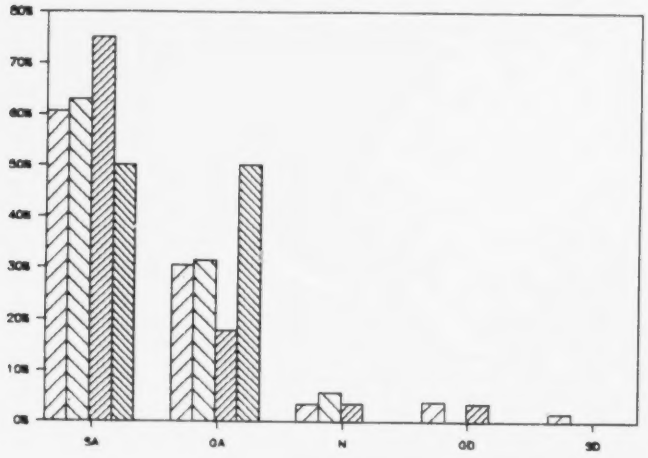
2. LABORATORY EXPERIENCE



3. LIBRARY

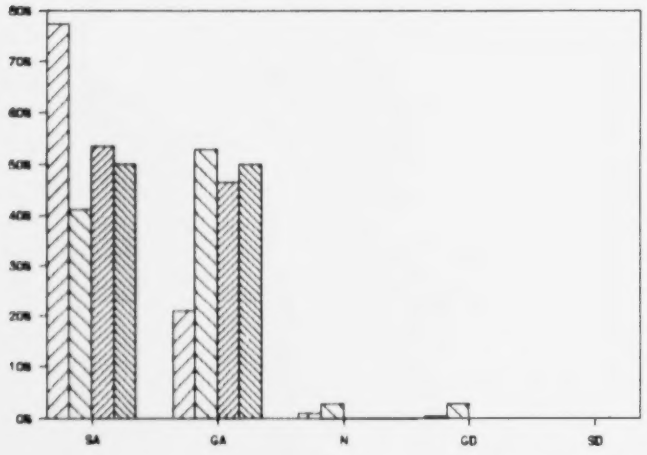


4. LIFE-LONG LEARNING

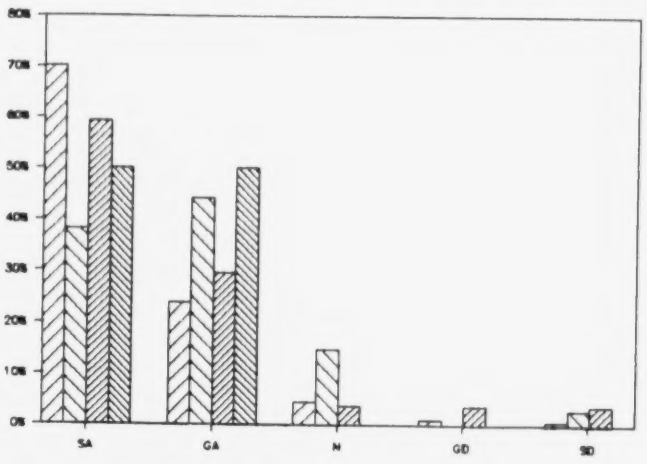


RESOURCE ALLOCATIONS

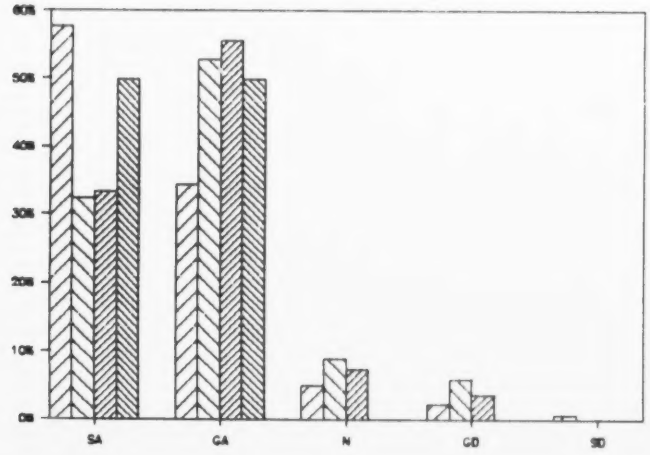
1. INDUSTRY FINANCIAL SUPPORT



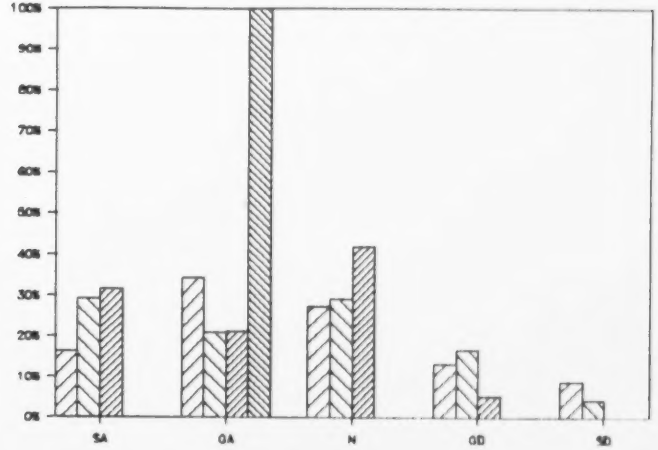
2. COMPUTER MAINTENANCE



3. DONATED EQUIPMENT

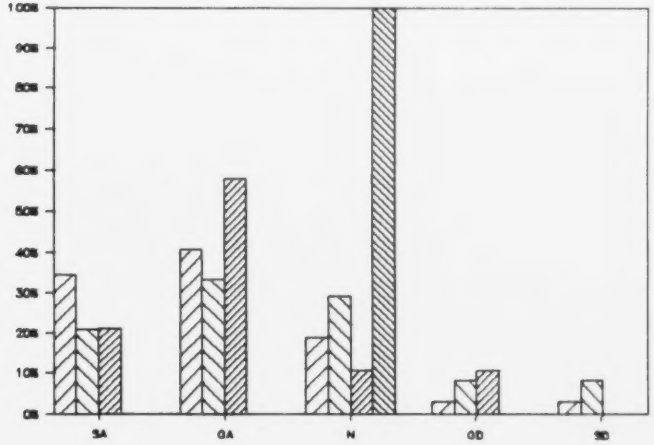


4. UTILIZE REGIONAL LABORATORIES

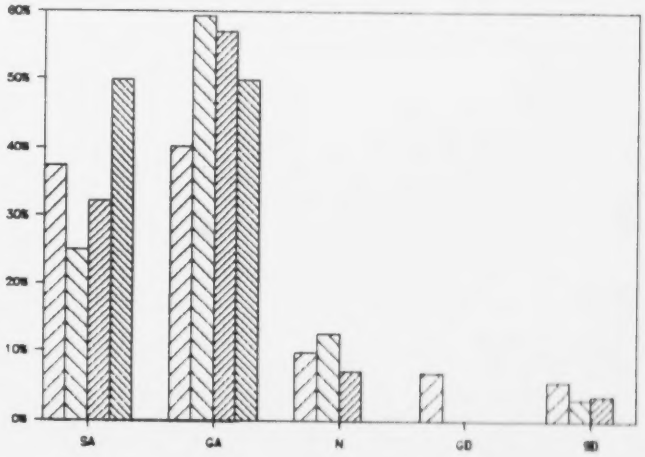


ACCREDITATION CRITERIA

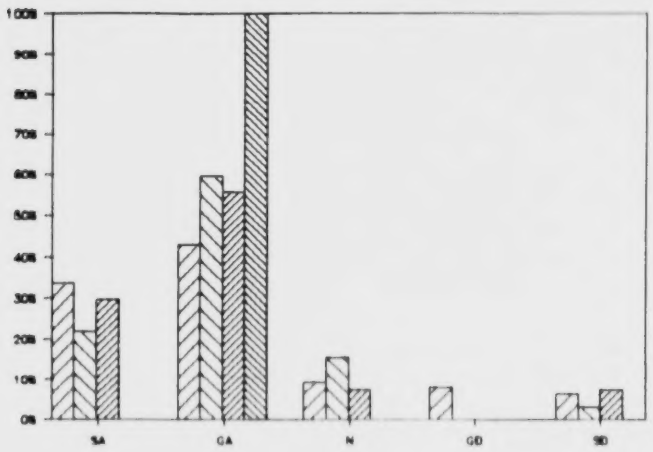
5. TECH. STAFF TRAINED BY INDUSTRY



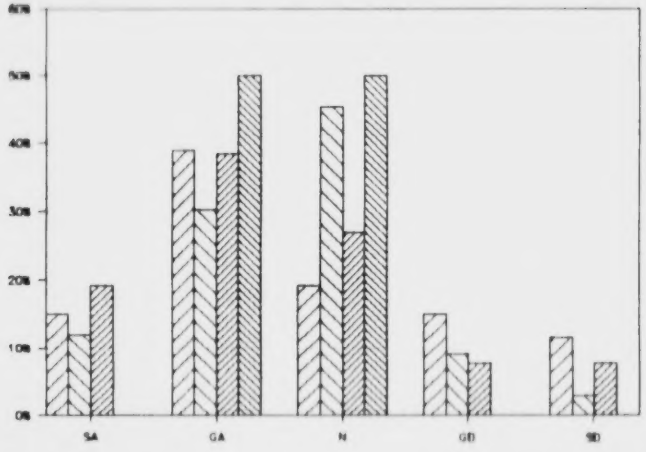
1. LABORATORY REQUIREMENT



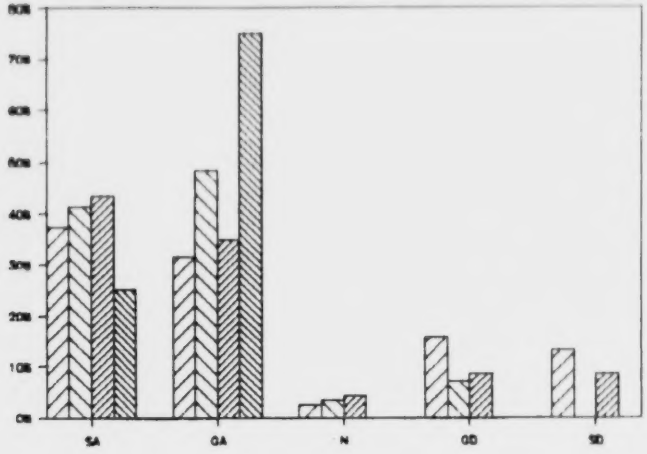
2. COMPUTER REQUIREMENT



3. "STRAWMAN" CRITERIA

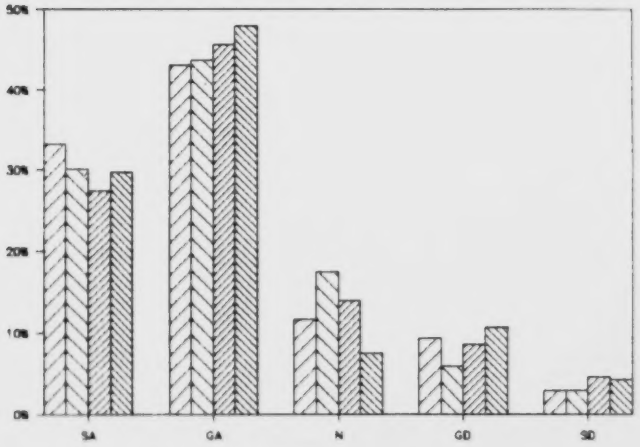


C1. SPECIFIC CRITERIA

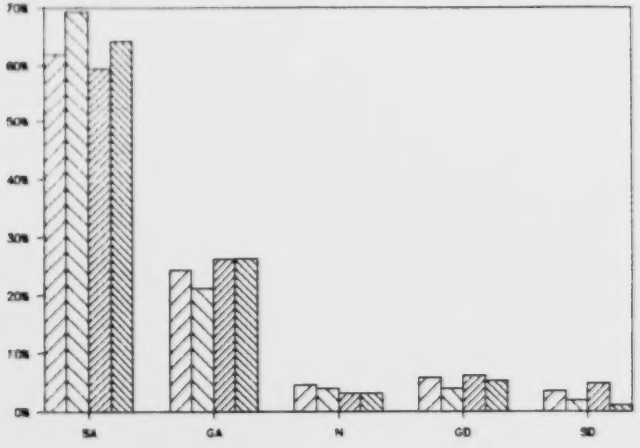


FACULTY RESOLUTIONS

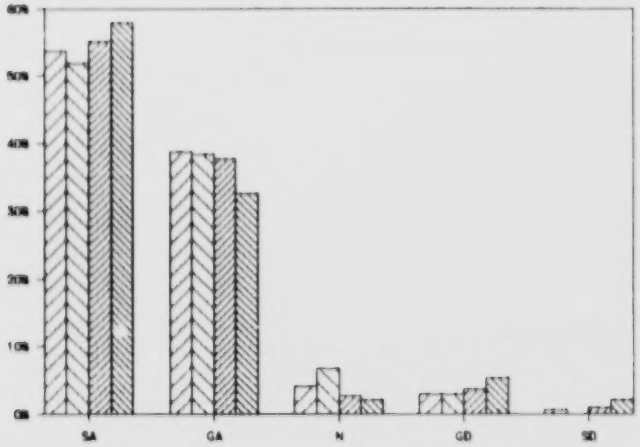
1. GRADUATE PROGRAM ATTRACTIVENESS



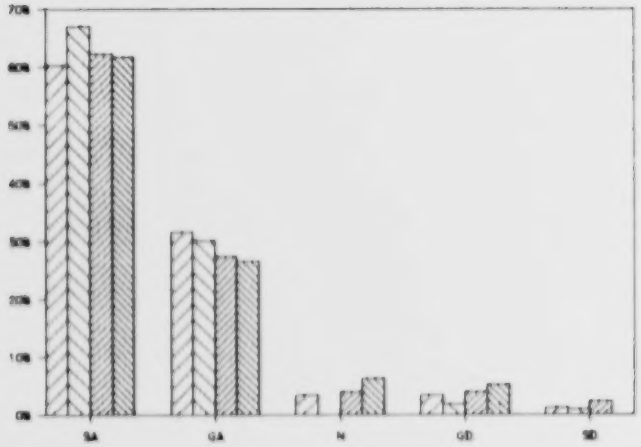
3. PROFICIENCY IN ENGLISH

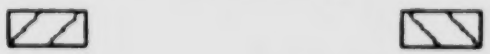


2. GRADUATE SUPPORT

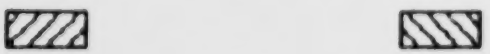


4. THE TEACHING FUNCTION



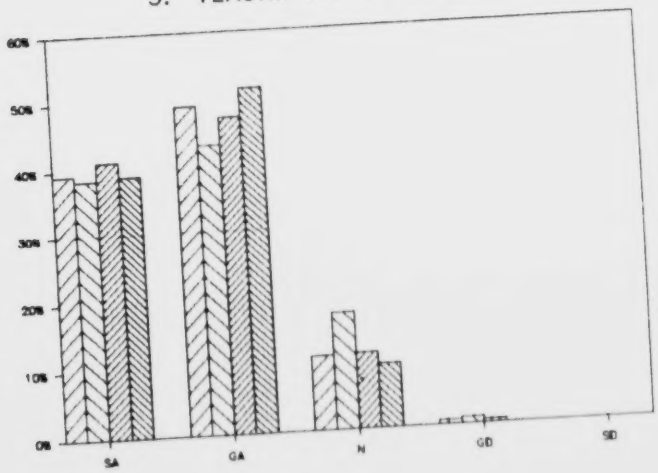


Licensed Prof. Engineer **Officer of Eng. Soc.**

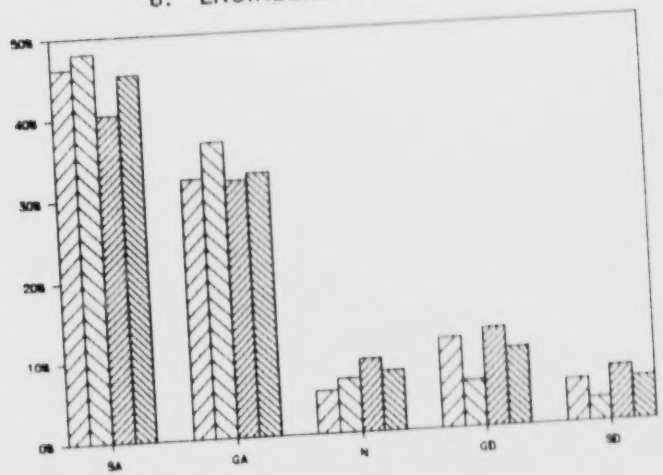


Member Prof./Tech. Soc. **Soc. Educational Comm.**

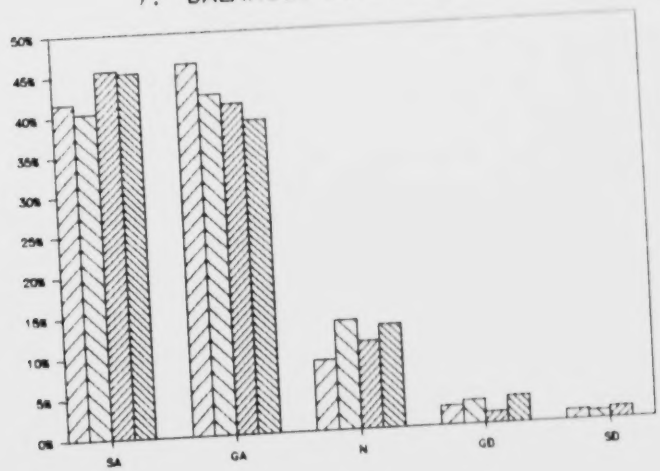
5. TEACHING WORKSHOPS



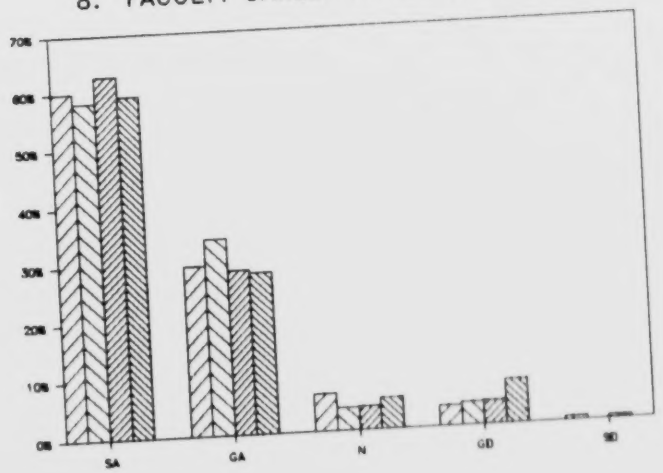
6. ENGINEERING PRACTICE



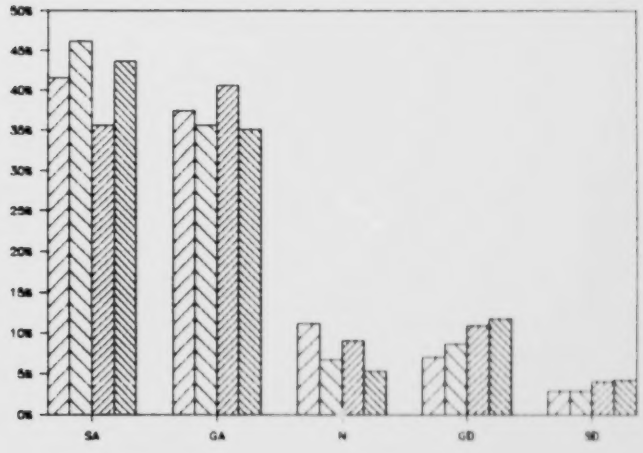
7. BALANCED DEPARTMENTS



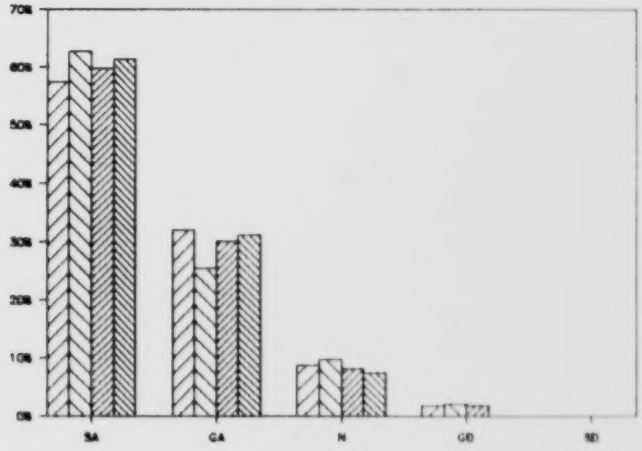
8. FACULTY CAREER ATTRACTIVENESS



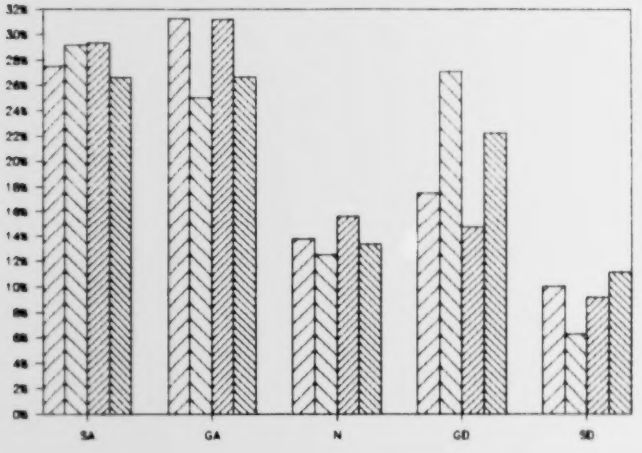
9. PROFESSIONAL COMPETENCE



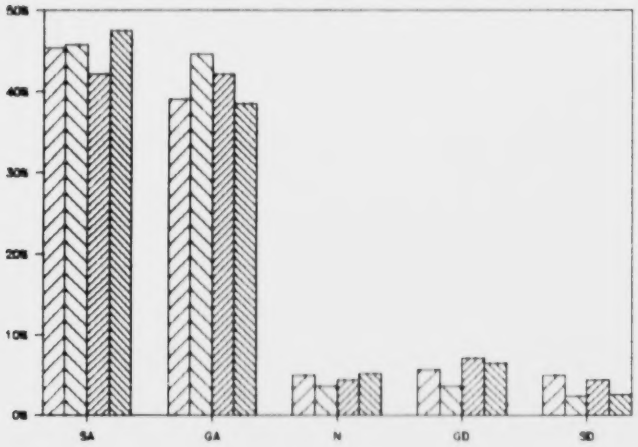
10. INTERACTION WITH INDUSTRY



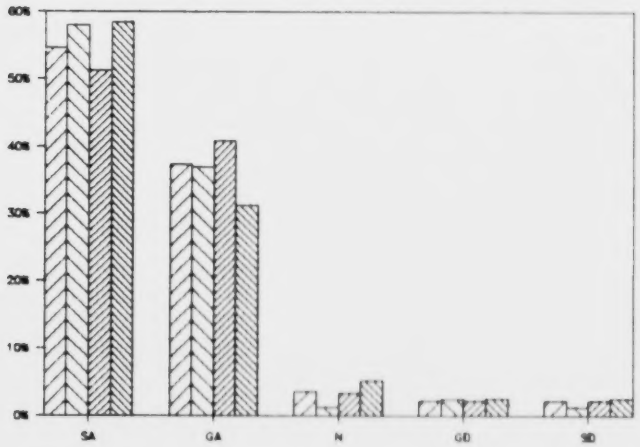
11. UTILIZE FACULTY W/O DOCATORATES



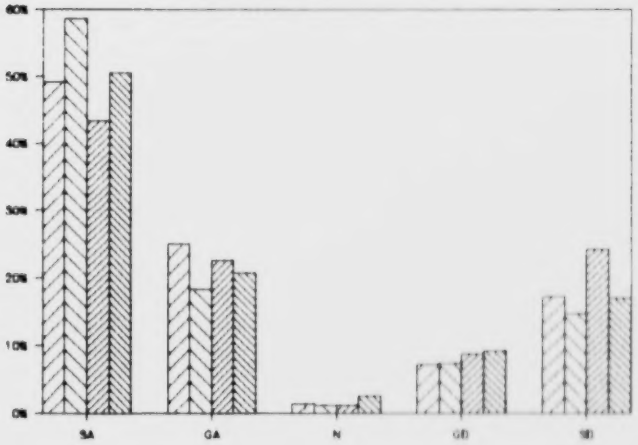
A1. GRADUATE PROGRAM ATTRACTIVENESS



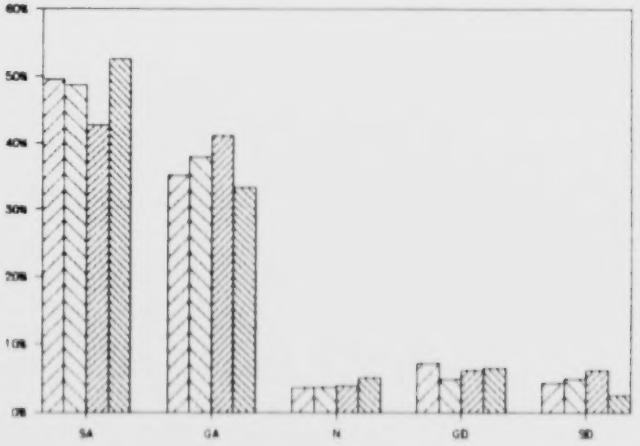
A3. PROFESSIONAL COMPETENCE



A2. PROFICIENCY IN ENGLISH

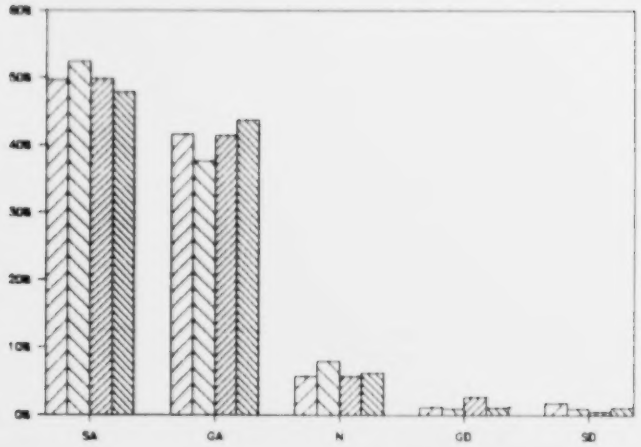


A4. UTILIZE FACULTY W/O DOCTORATES

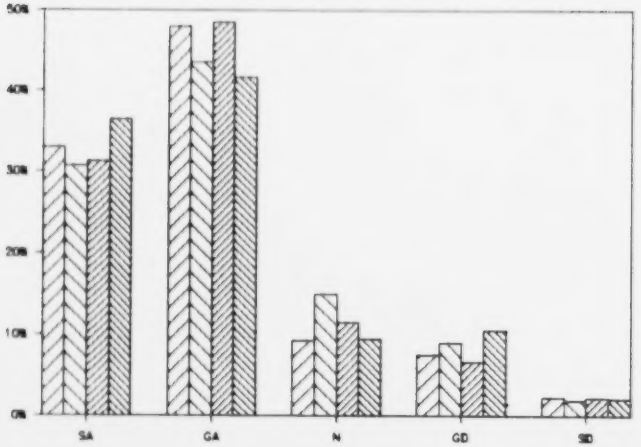


CURRICULUM ISSUES

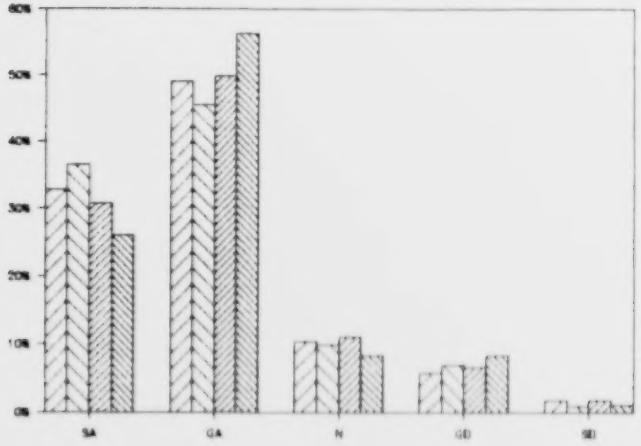
1. COMPUTER USE



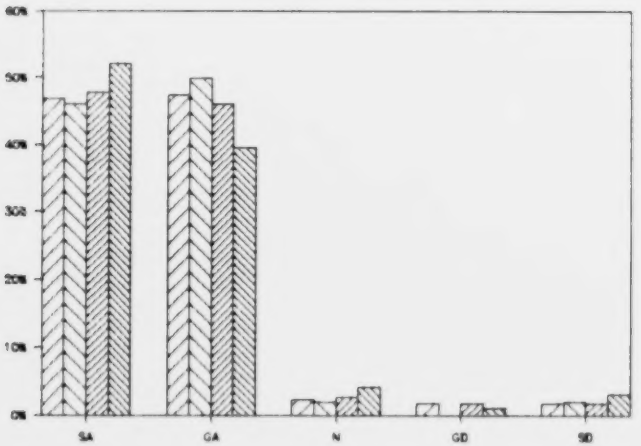
3. BASIC SCIENCE REQUIREMENT



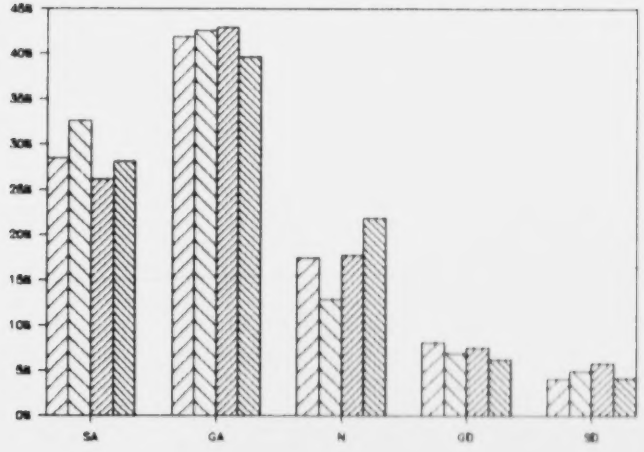
2. MANUFACTURING & CONSTRUCTION



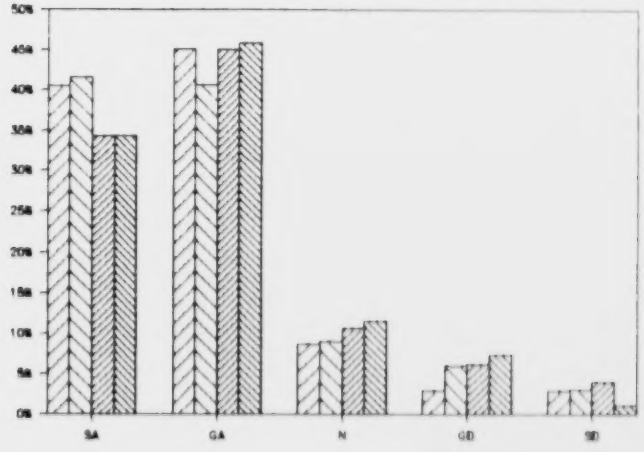
4. MATHEMATICS REQUIREMENT



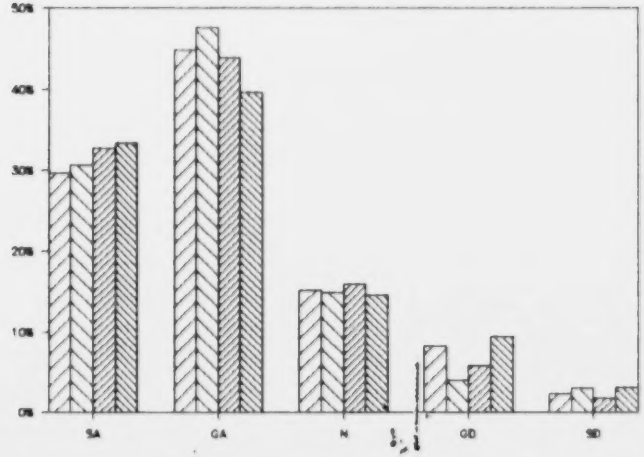
5. THE GLOBAL ECONOMY



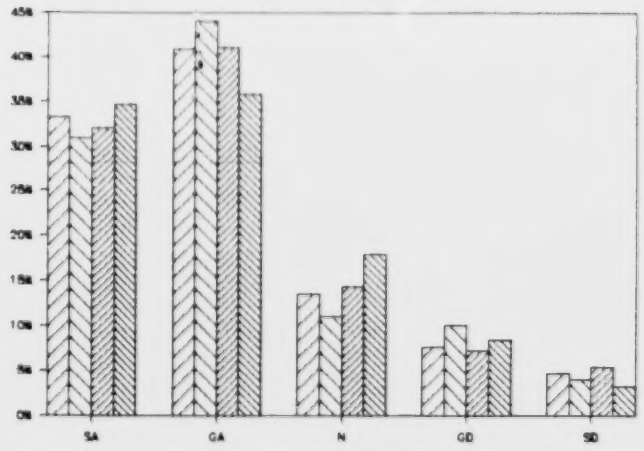
6. THE INDUSTRIAL ENVIRONMENT



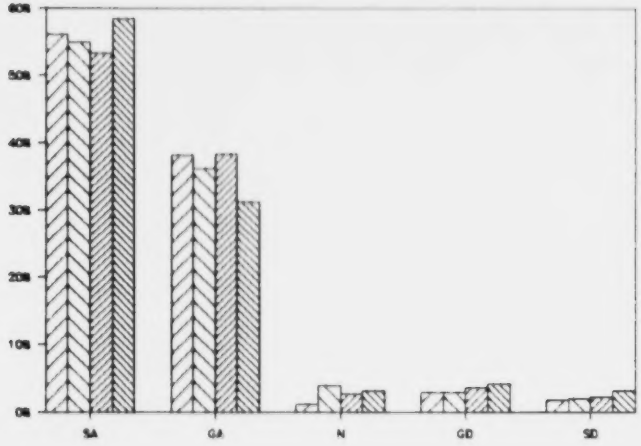
7. ENGINEERING SCIENCE CRITERIA



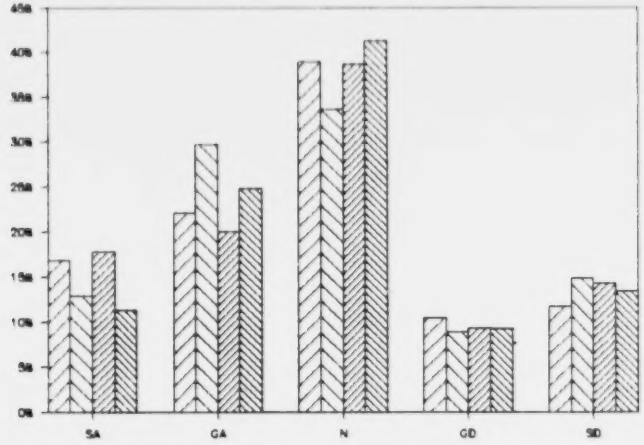
8. BASIC EDUCATION REQUIREMENT



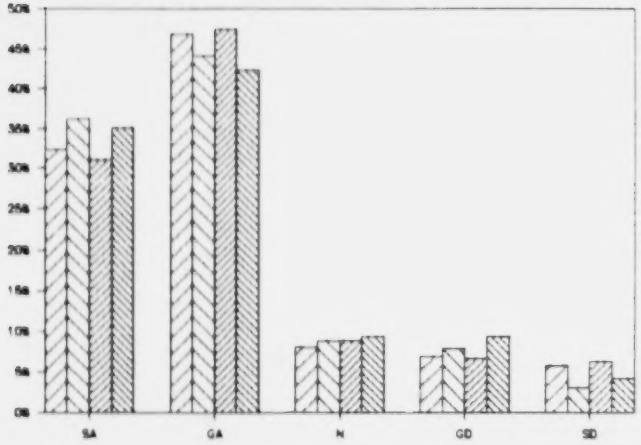
9. ENGINEERING DESIGN CRITERIA



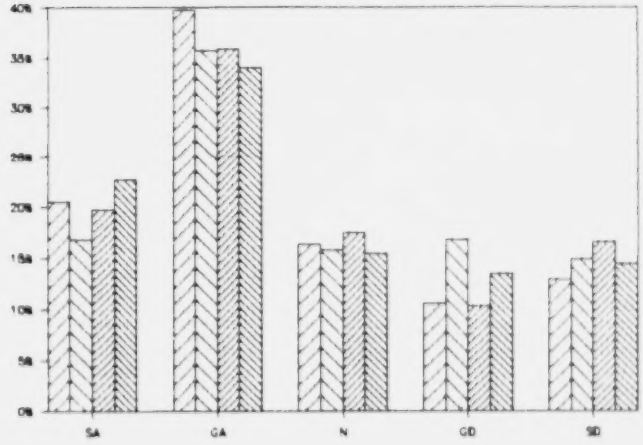
11. INTERNATIONAL ACCREDITATION



10. LIBERAL ARTS & HUMANITIES

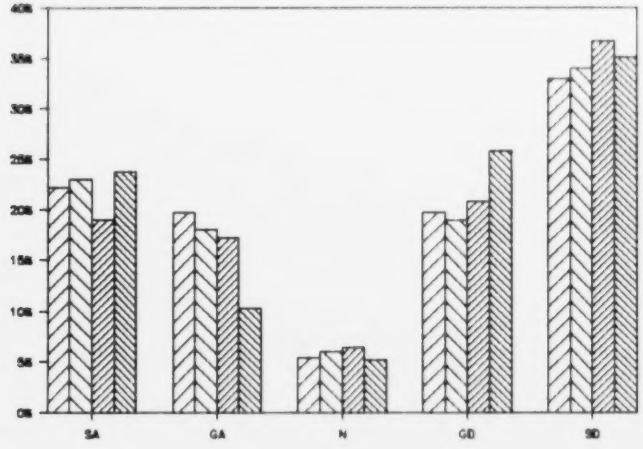


12. PROFESSIONAL-LEVEL ACCREDITATION

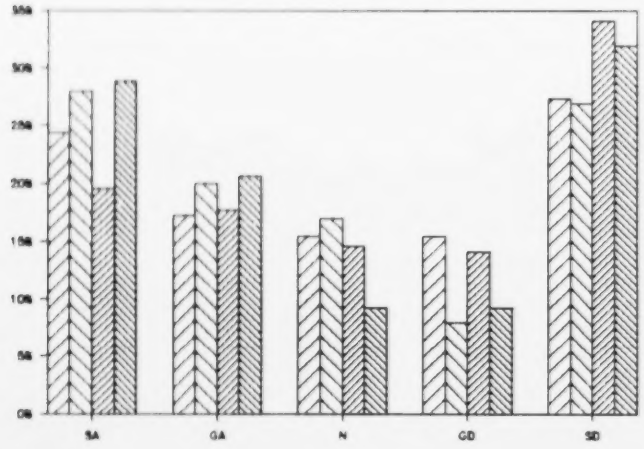


13. ACADEMIC PROGRAM LENGTH

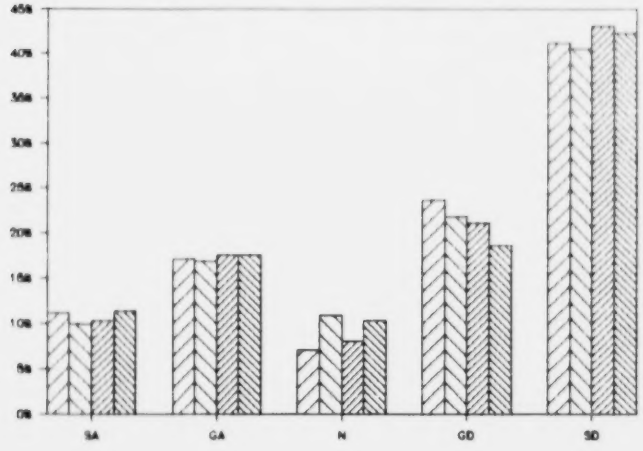
I. ENCOURAGE 5-YEAR PROGRAM



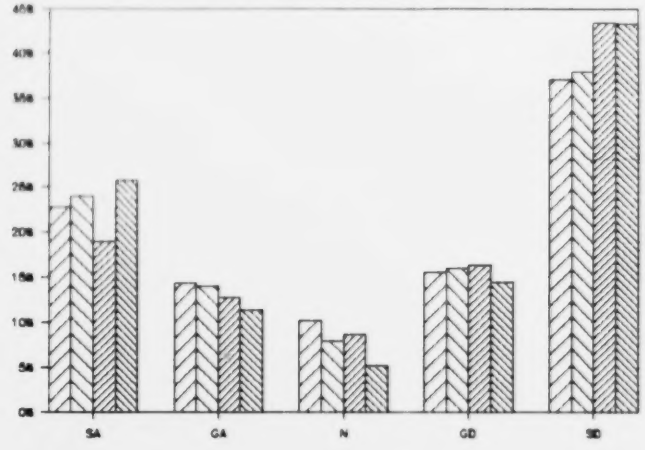
III. REINSTITUTE DUAL LEVEL



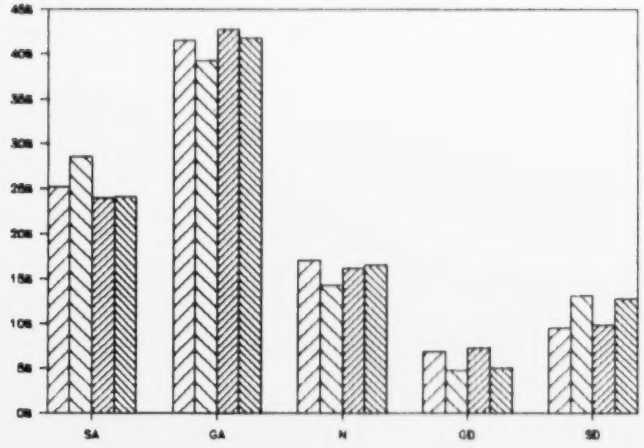
II. REDUCE TECHNICAL CONTENT



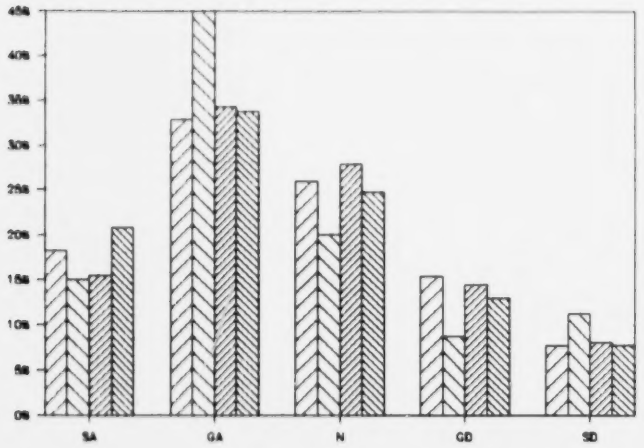
IV. PRESCRIBE 5-YEARS BY 1995



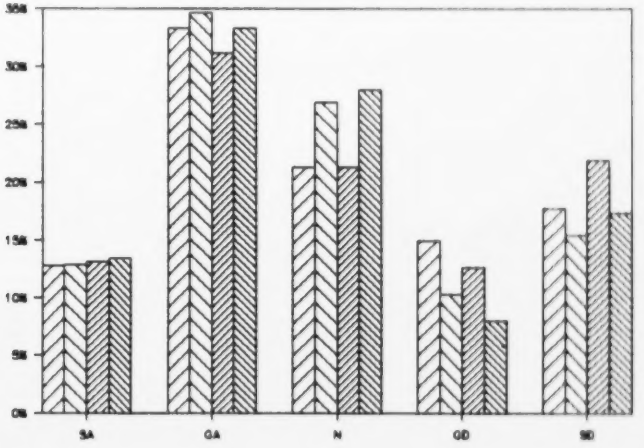
14. REQUIRE STATISTICS



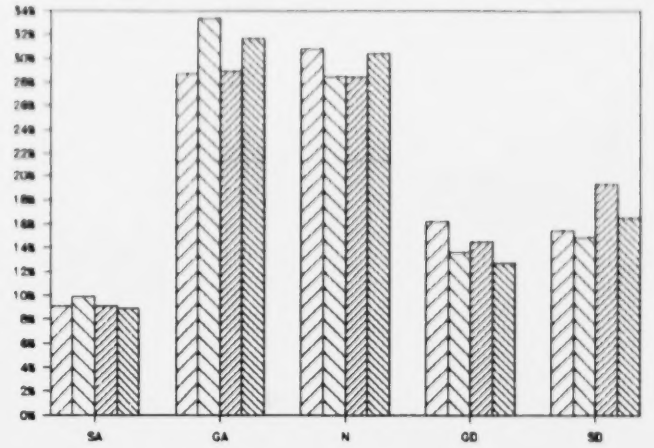
15. HEALTH & SAFETY



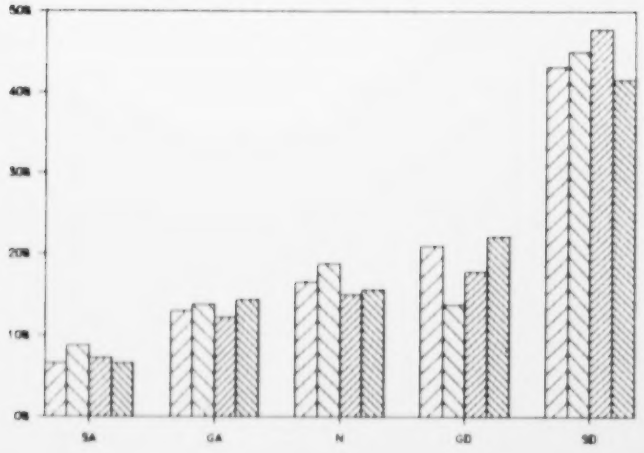
16. LANGUAGE ADMISSION REQUIREMENT



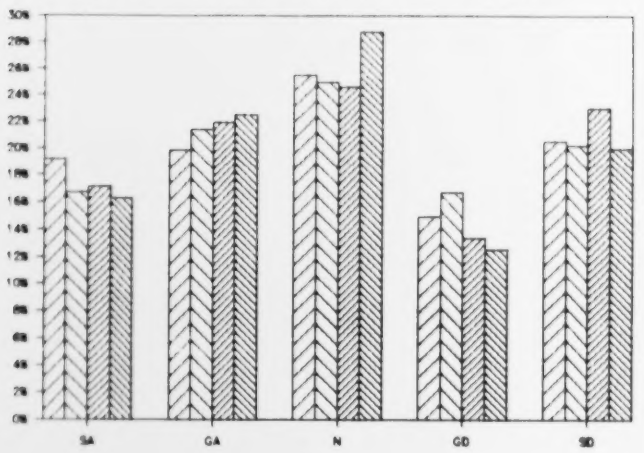
17. REQUIRE ORIENTAL LANGUAGES



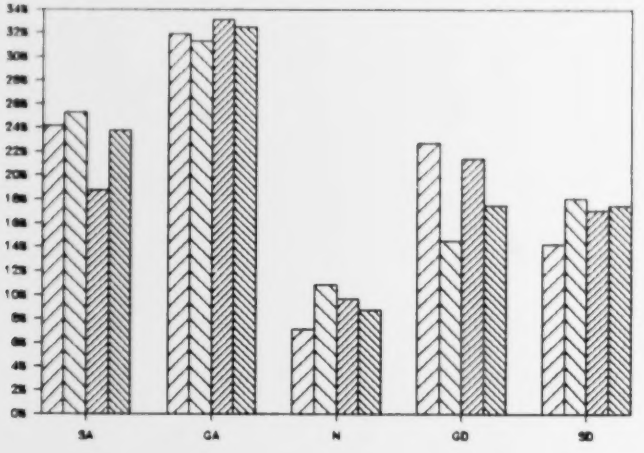
18. D. ENG. AS PROFESSIONAL DEGREE



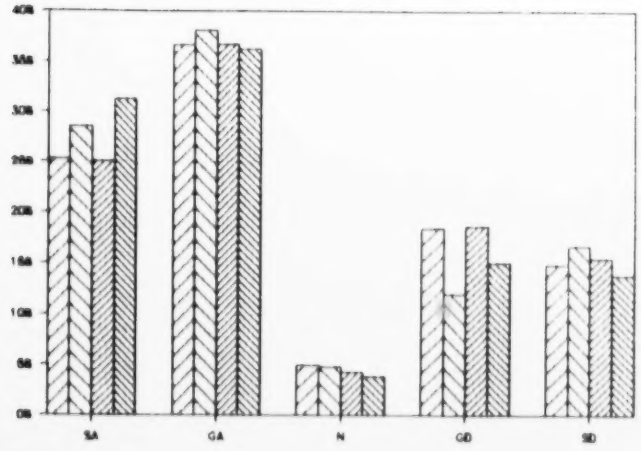
B1. INTERNATIONAL ACCREDITATION



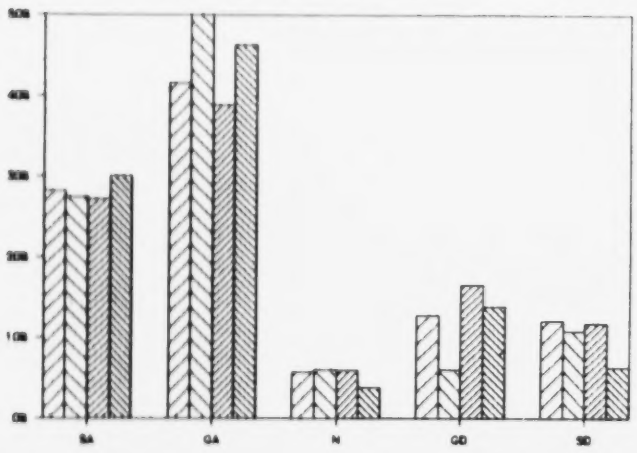
B2. PROFESSIONAL-LEVEL ACCREDITATION



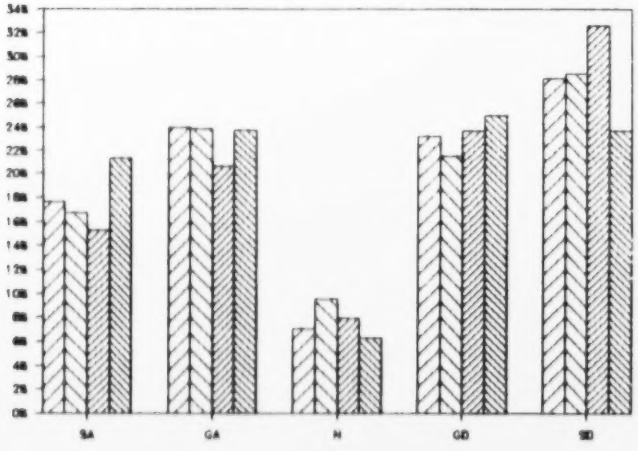
B3. REQUIRE STATISTICS



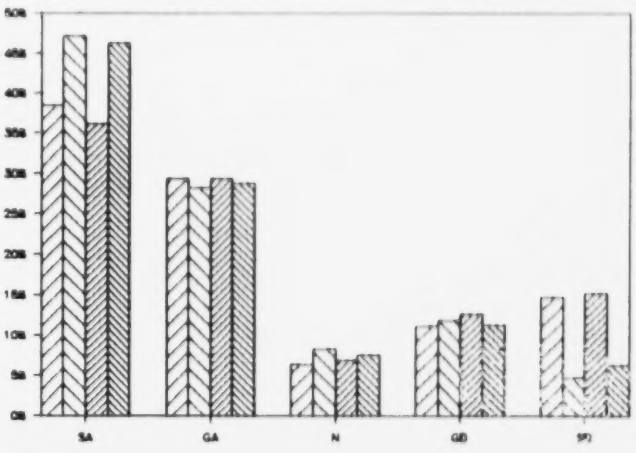
B4. HEALTH & SAFETY



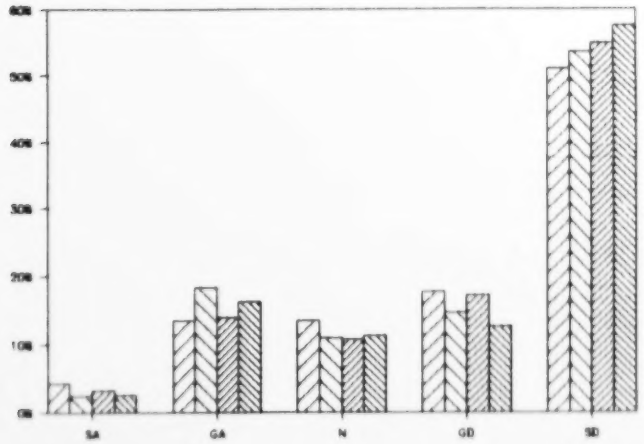
B5. LANGUAGE ADMISSION REQUIREMENT



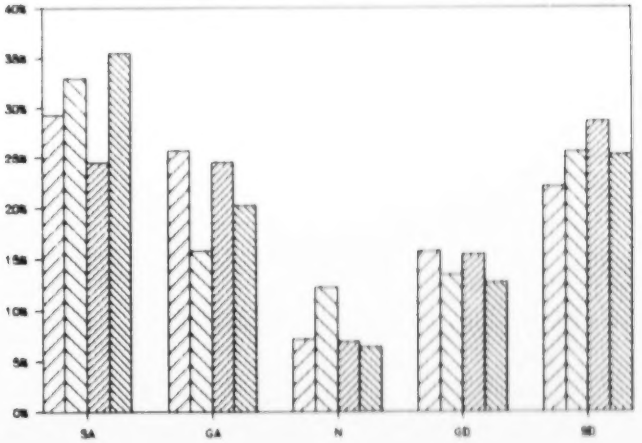
B6. MASTERY OF ENGLISH REQUIREMENT



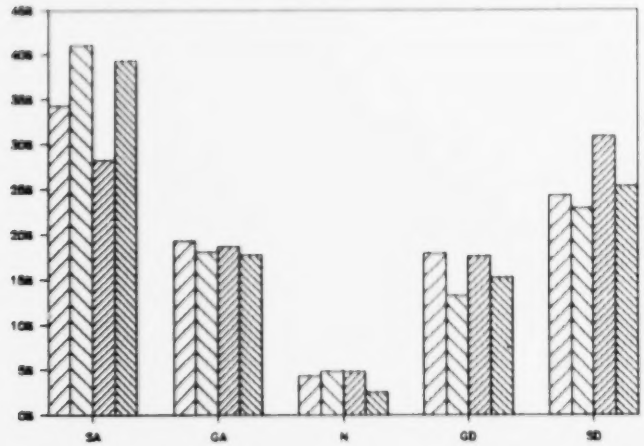
B7. REQUIRE ORIENTAL LANGUAGES



B9. REINSTITUTE DUAL-LEVEL ACCRED.

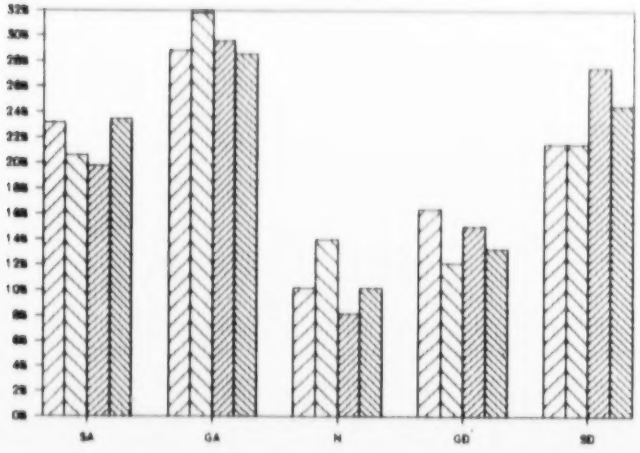


B8. ENCOURAGE 5-YEAR PROGRAM

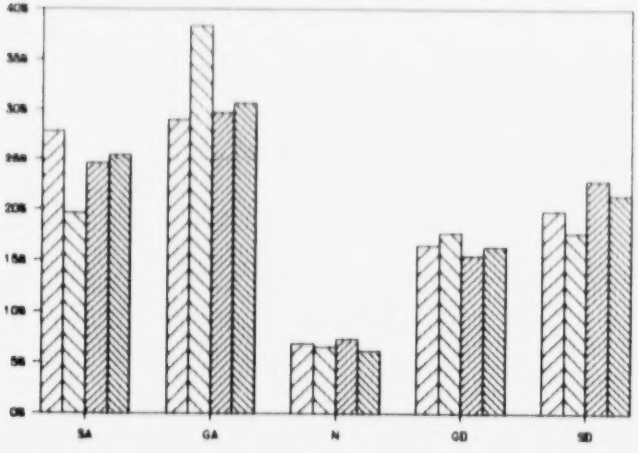


BROAD ACADEMIC ISSUES

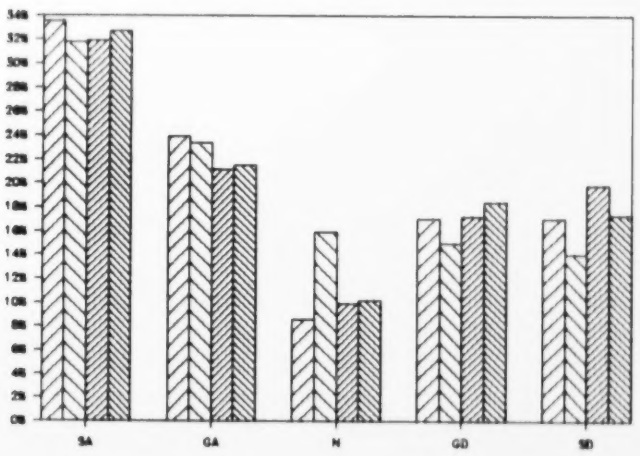
1. LIMITING PROGRAMS



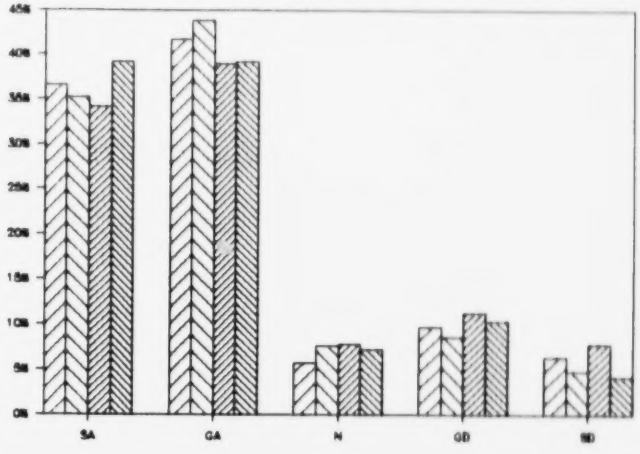
2. MORATORIUM ON PhD PROGRAMS



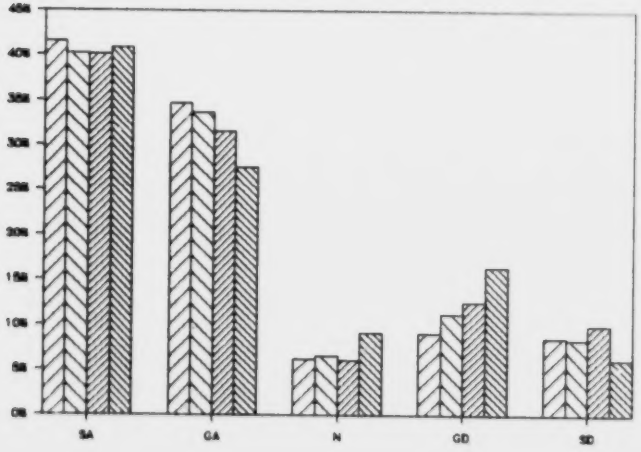
3. MORATORIUM ON NEW SCHOOLS



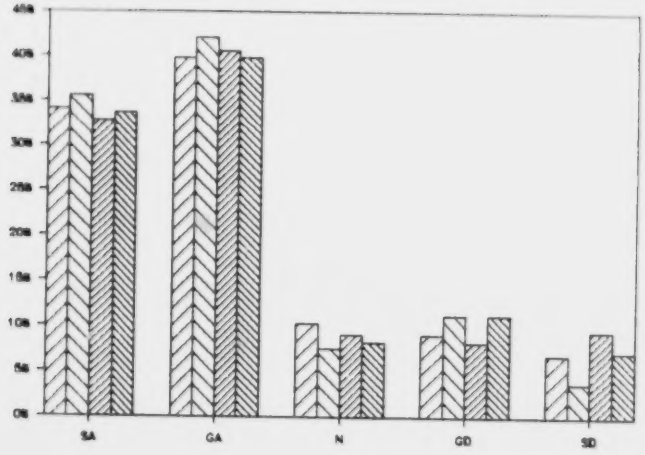
4. FACULTY & LAB REQUIREMENTS



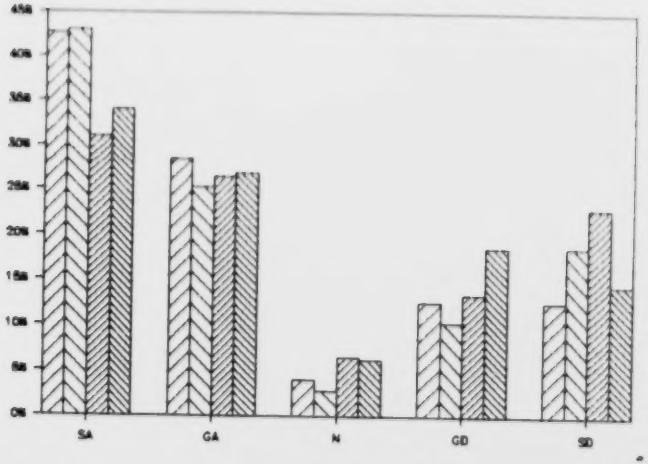
5. ADMISSIONS REQUIREMENTS



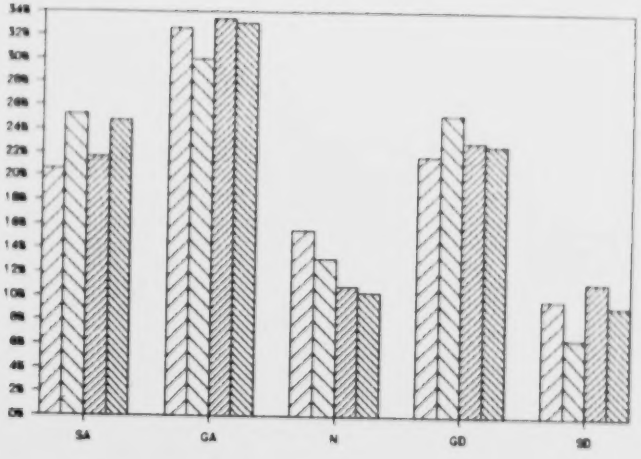
7. ADVISORY COMMITTEES



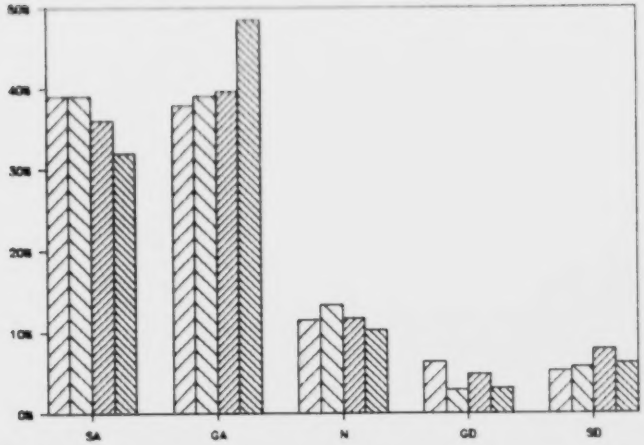
6. REGISTRATION FOR TEACHING



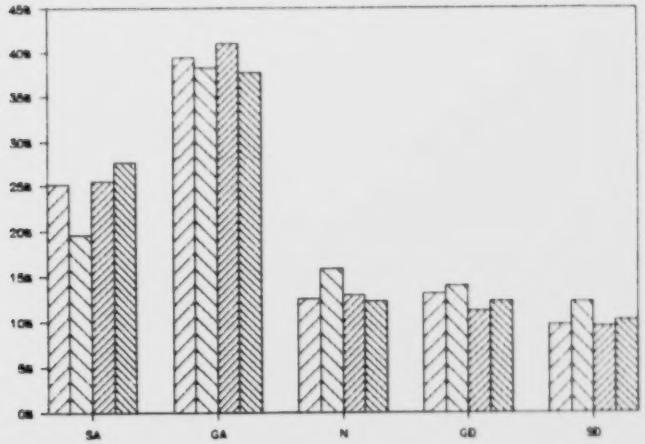
8. QUALITY GOALS



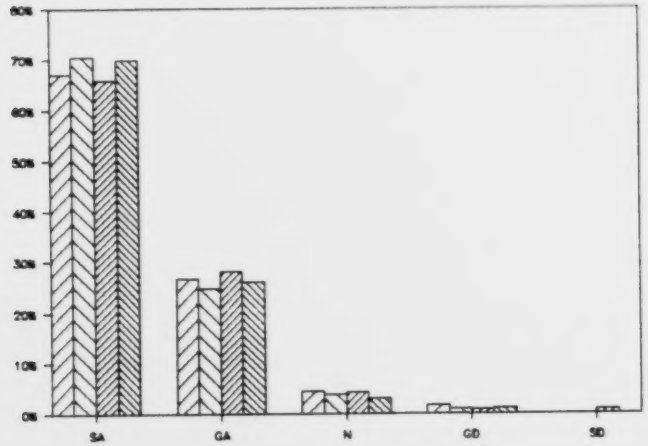
9. UNIVERSITY ENVIRONMENT



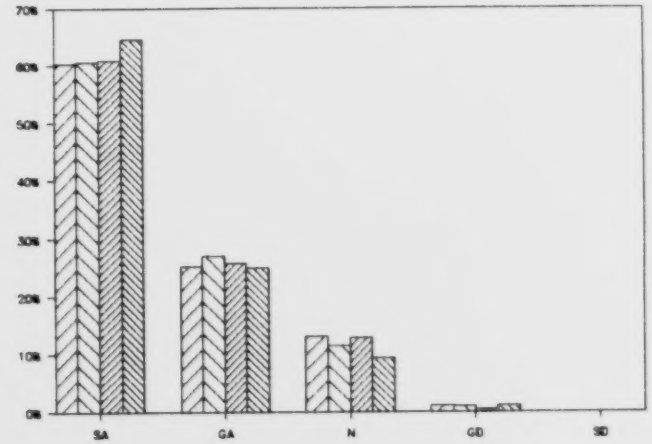
10. CONTINUING EDUCATION



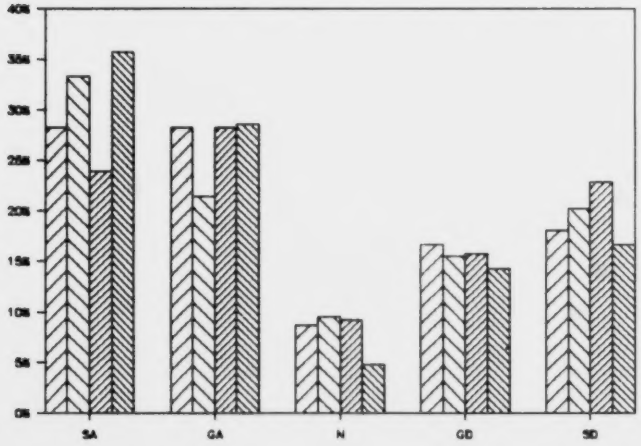
11. COMPETITIVENESS



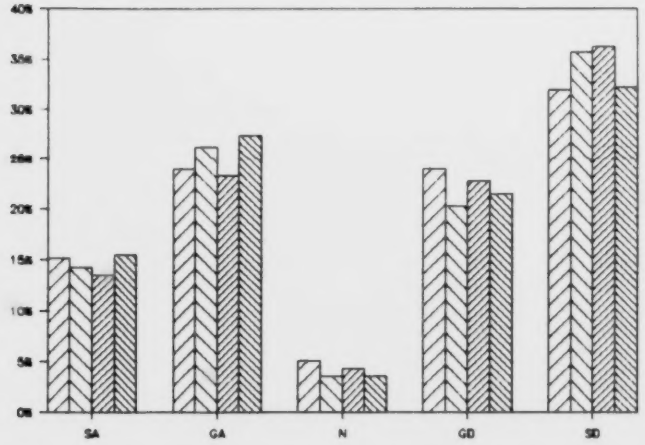
12. NATIONAL SCIENCE BOARD



D1. LIMITING PROGRAMS



D2. MORATORIUM ON PhD PROGRAMS



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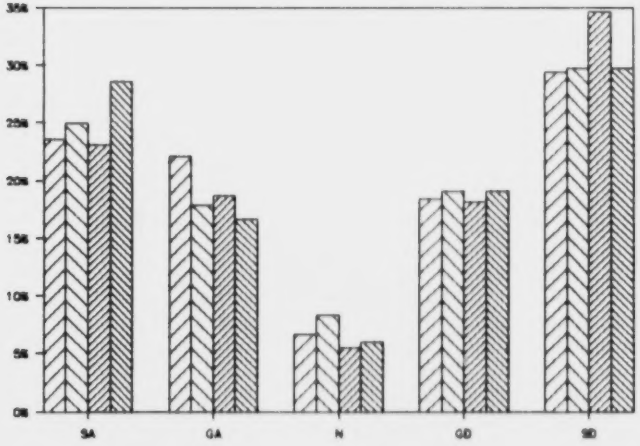

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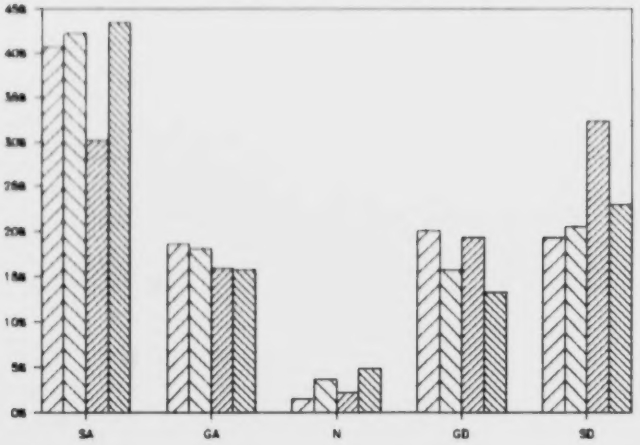

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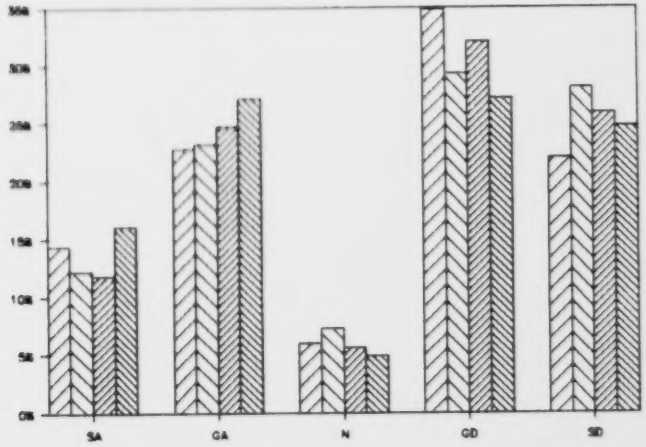

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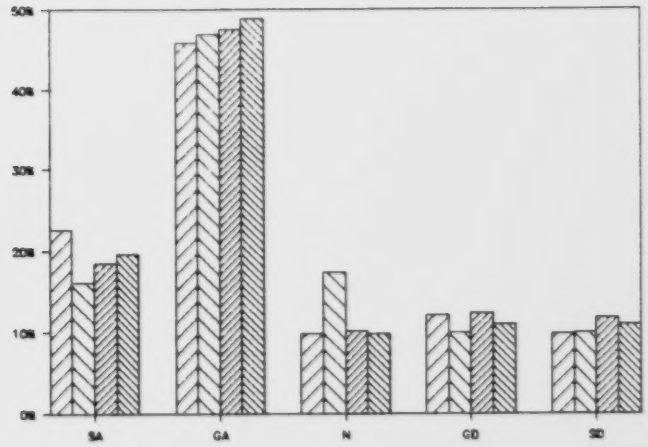

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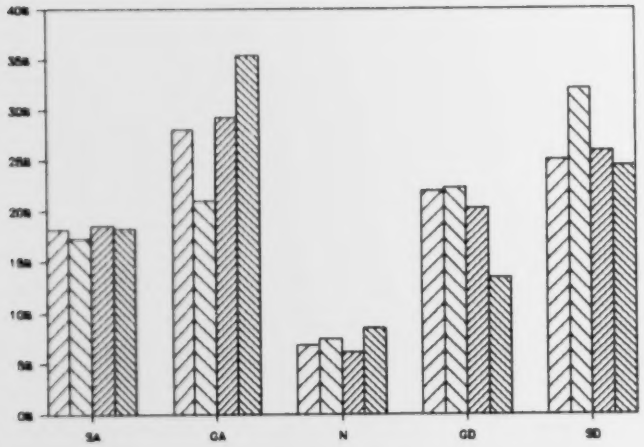

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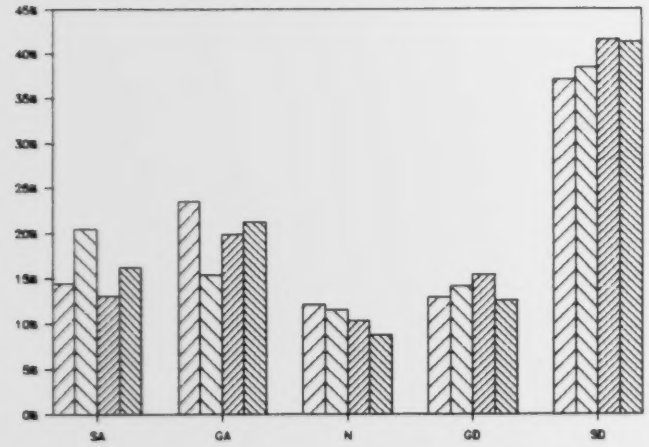

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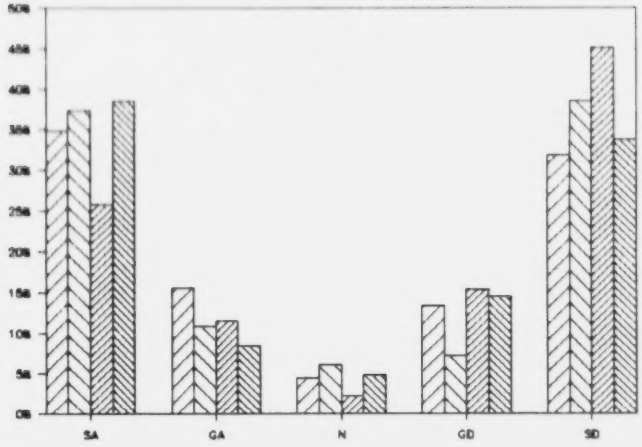
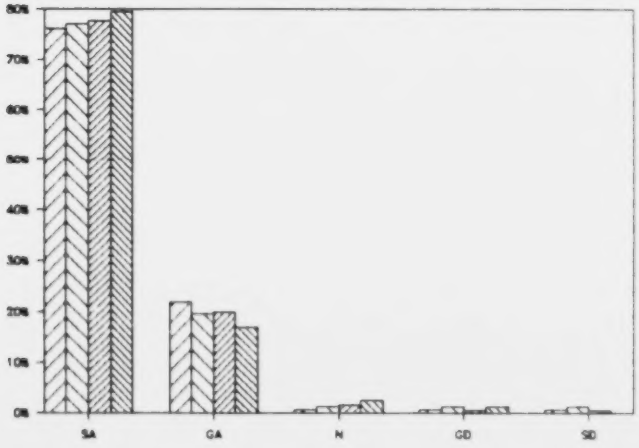


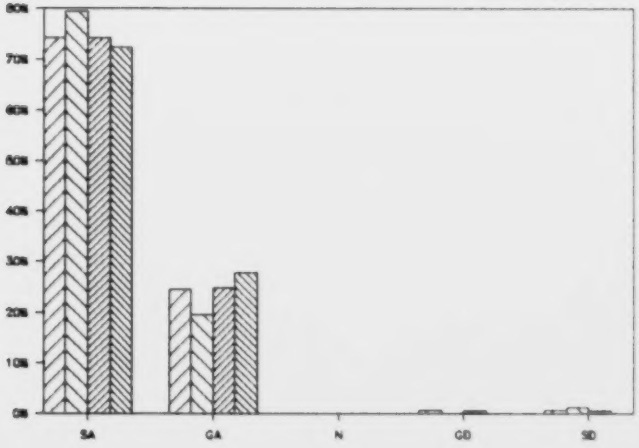
LABORATORY, COMPUTER, AND EDUCATIONAL TECHNOLOGY ISSUES

ROLE OF TECHNOLOGY

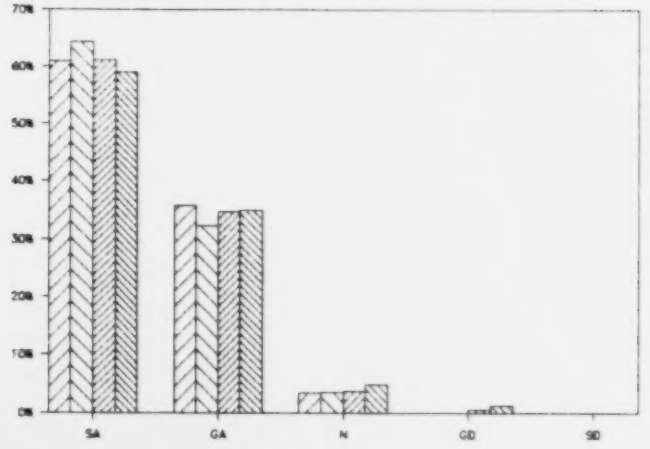
1. FOCUS ON TEACHING



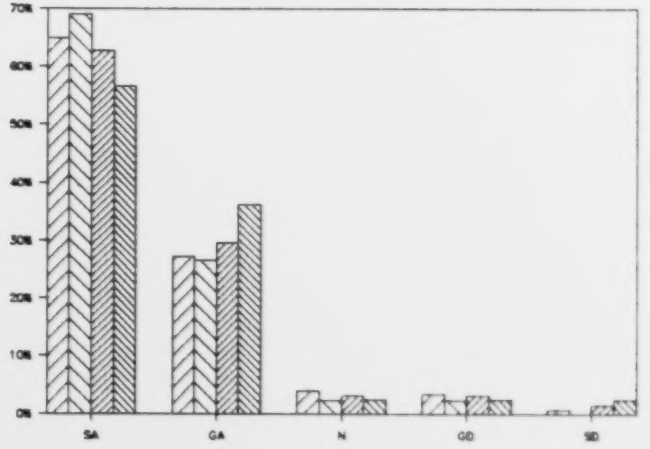
2. LABORATORY EXPERIENCE



3. LIBRARY

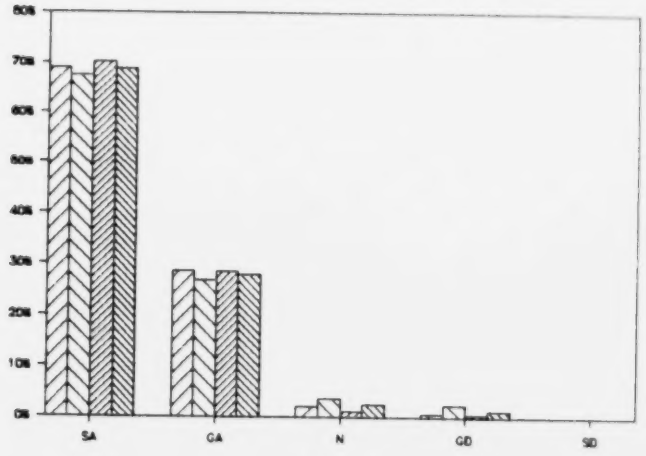


4. LIFE-LONG LEARNING

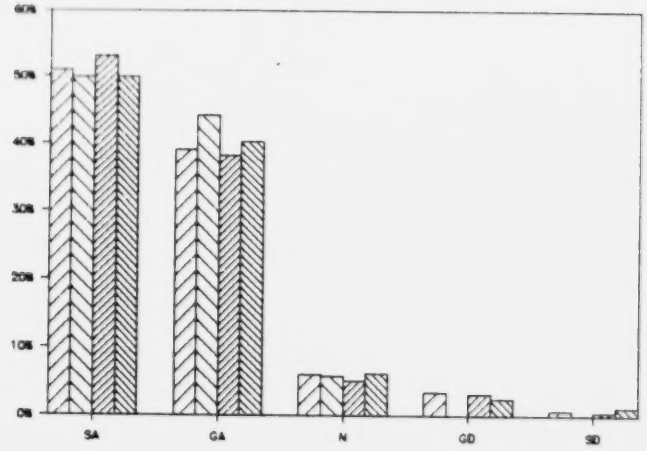


RESOURCE ALLOCATIONS

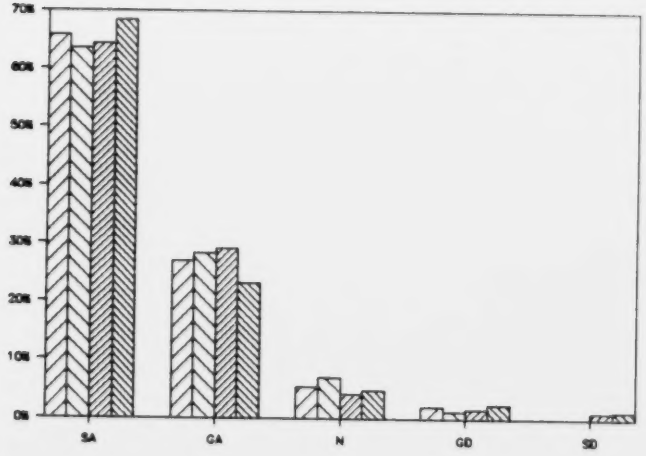
1. INDUSTRY FINANCIAL SUPPORT



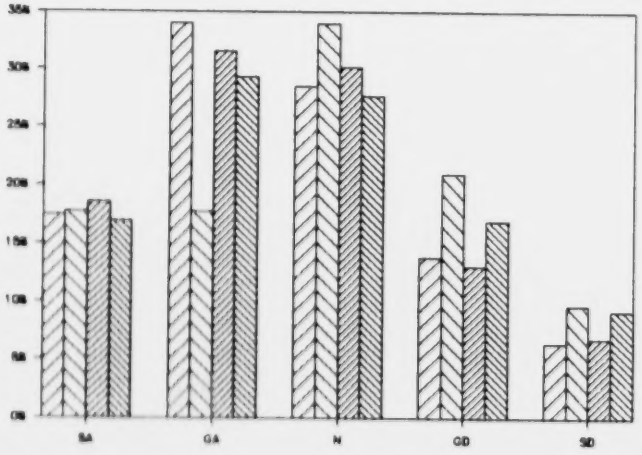
3. DONATED EQUIPMENT



2. COMPUTER MAINTENANCE

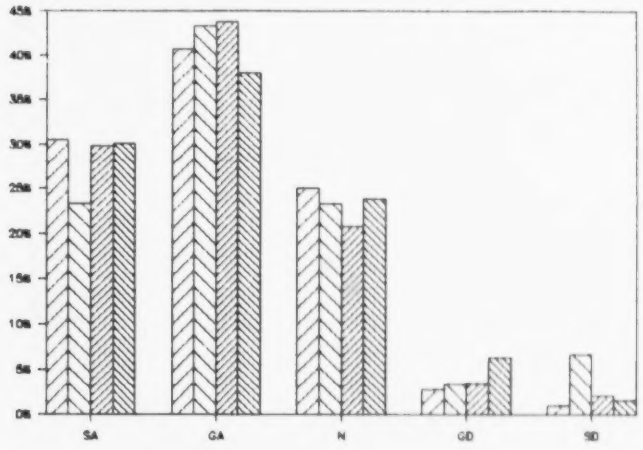


4. UTILIZE REGIONAL LABORATORIES

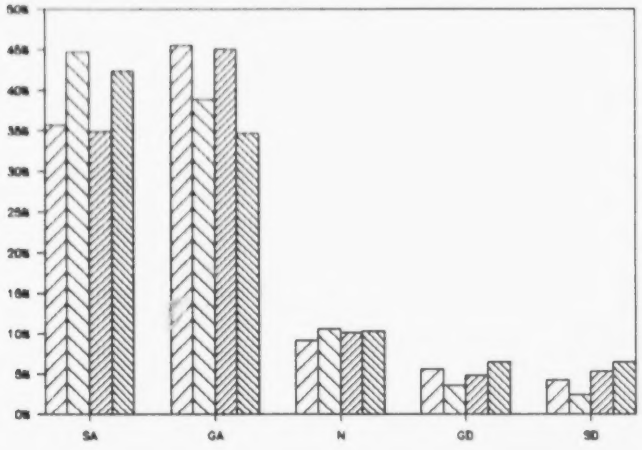


ACCREDITATION CRITERIA

5. TECHNICAL STAFF TRAINED BY INDUSTRY



1. LABORATORY REQUIRMENT



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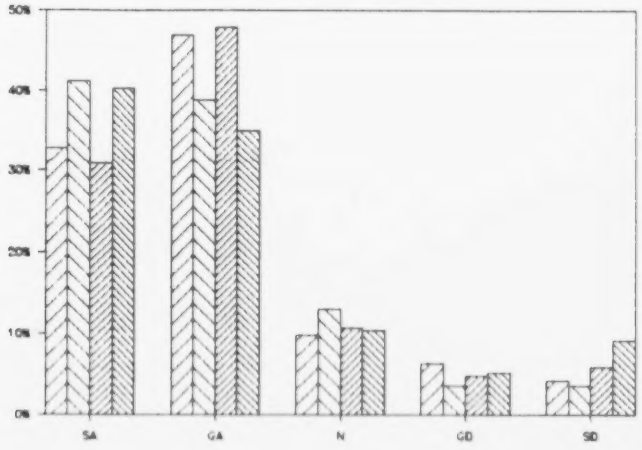
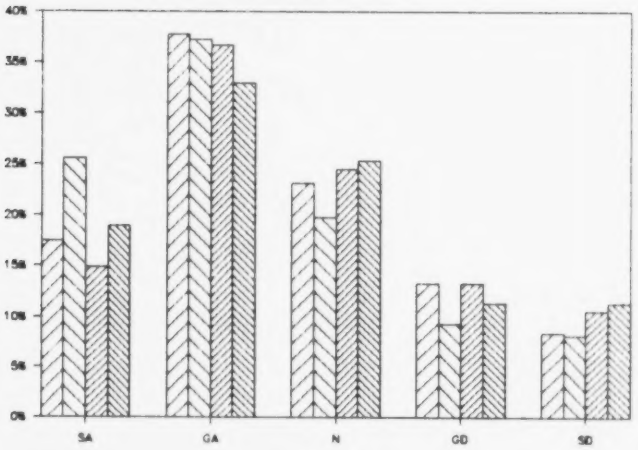
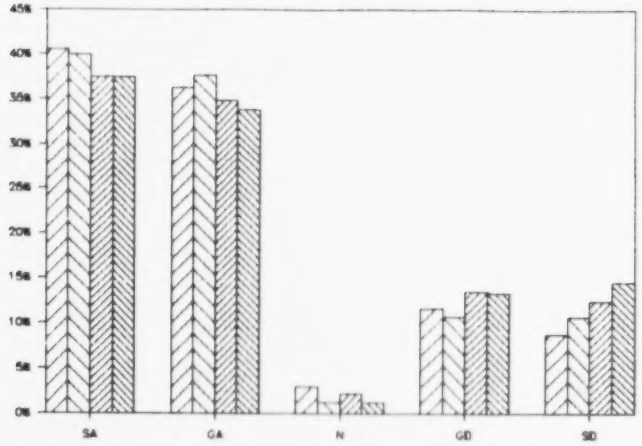


3. "STRAWMAN" CRITERIA



C1. SPECIFIC CRITERIA



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APPENDIX F

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APPENDIX G

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NCQE

APPENDIX H

Pre–Congress Packet

NC2E National Congress on Engineering Education

C/o ABET 345 E. 47th St., New York, NY 10017 • (212) 705-7685 • Telex: 5101012914 ABET NYO

EXECUTIVE COMMITTEE

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President, National Technological University

Dr. L.S. (Skip) Fletcher
Curriculum
President, American Society of Mechanical Engineers

Dr. Bruno O. Weinschel
Faculty
President, Institute of Electrical and Electronics Engineers

October 31, 1986

Dear Participant:

Enclosed is the material developed by the Major Issues Committees for your consideration and action at the National Congress on Engineering Education (NC2E) on November 20-22, 1986.

You are urged to read this material carefully prior to attending NC2E. You may forward comments on each section to ABET Headquarters at 345 E. 47th Street, New York, NY 10017, or use ITT Dialcom COMPMAIL number CMP1207, or telex number 5101012914 (ABET NYO). All inputs will be passed on to the chairs of the Major Issues Committees for their cognizance and possible incorporation at the congress.

When you register at NC2E, we will have a special set of forms for you to fill out. We will use these forms to obtain a true profile of the attendees. Your responses will be confidential and will be treated as such. We will only use them in the statistical analysis of the data generated at NC2E. Not only will you be asked to prepare a profile, but you will also be asked at each session to record your votes on specially prepared sheets that will relate to your profile sheet.

You will note from the program that the congress is designed as a single meeting. Only one session will be held at a time, and that session will cover one issue only. This is purposely done to obtain full participation for each issue.

The results of the congress, including full proceedings and analysis of the votes on all resolutions, will be distributed early next year. Meanwhile, ABET and all of the engineering societies with curricular responsibility, as well as the higher education community, will be asked to begin implementing the consensus resolutions.

-Continued-

At the banquet on Thursday night, November 20, our speaker will be:

Dr. Roland W. Schmitt
Chairman of the National Science Board, and
Senior Vice President and Chief Scientist,
General Electric Company
on the topic
"The Creative Mind and the Competitive Challenge"

We also will enjoy the presence of Dr. Linton E. Grinter at the presentation of his namesake Distinguished Service Award to:

Mr. Paul Allmendinger
Executive Director
American Society of Mechanical Engineers

Your attendance at and contribution to this unique event are highly valued. We believe that NC2E will be a cornerstone for the future of engineering education.

Sincerely,

David R. Reyes-Guerra, P.E.
ABET Executive Director and
NC2E Secretary

DRR-G:sld

NC2E

National Congress on Engineering Education

Program Preprints

INTRODUCTION

Dr. Russel C. Jones, Co-Chair, Program Committee

NC2E **National Congress on Engineering Education**
c/o ABET 345 E. 47th St., New York, NY 10017 • (212) 705-7685 • Telex: 5101012914 ABET NYO

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Boston University
145 Bay State Road
Boston, Massachusetts 02215

October 31, 1986

TO: NC2E Participants

FROM: Russel C. Jones

SUBJECT: Program Preprints

The Accreditation Board for Engineering and Technology is pleased that you have registered for the National Congress on Engineering Education. We look forward to interacting with you in Washington in late November.

The Program Planning Committee has attempted to structure discussions for this important Congress in order to get maximum effectiveness from our three days together. We have enclosed for your review a package of documentation which we hope will stimulate your thoughts prior to your arrival in Washington for the conference. This package of documents is arranged around our three main plenary topics--Faculty Issues, Curriculum Issues, and Computer/Laboratory/Educational Technology Issues. Within each package we have attempted to identify the most important reports written over the past couple of years which relate to that topic, draw a series of conclusions from those reports which we believe are a consensus of the profession at this point in time, then structure resolutions so that we can test where participants in NC2E feel that the education of our engineers should be moving over the next decade or two.

During the Congress itself, speakers will highlight the major topics raised in the attached documentation, and will amplify those which the Program Committee has felt are most important or most controversial. At the end of each half-day plenary session we will be taking initial

NC2E

opinions from the assembled Congress in the form of written ballots on the draft resolutions contained in this mailing. The three major Issues/Resolutions Committees will take that material as guidance, and will then reshape their resolutions for final consideration and voting at the Saturday morning wrap-up session. At noon-time on Saturday the Program Review Committee, consisting of representatives from each of the Societies and other groups sponsoring NC2E, will meet to determine how to move from resolutions to effective implementation of directions set by the Congress. Over the weeks and months beyond that point we hope that ABET and the other Societies will be stimulated by and guided by the output of the Congress, with the eventual goal being significant strengthening of engineering education.

Please digest the enclosed material, and come prepared to debate the topics which you deem most appropriate. We look forward to seeing you next month in Washington.

Russel C. Jones

RCJ/scm

Enclosures

"ENGINEERING EDUCATION ANSWERS THE CHALLENGE OF THE FUTURE"

CO-SPONSORED BY THE ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY (ABET)
AND THE NATION S LEADING ENGINEERING SOCIETIES, INDUSTRY AND GOVERNMENT

NCEE

National Congress on Engineering Education

Congress Program

ENGINEERING EDUCATION ANSWERS THE CHALLENGE OF THE FUTURE

Thursday, November 20

8:30-12:15 Pre-Registration — Quorum Room

12:00-2:00 **OPENING LUNCHEON** — Monet Suite

Distinguished Speaker:
Dr. Nam P. Suh
National Science Foundation

Presiding: Dr. Gene M. Nordby, NC2E Chairman

Conference Briefing: Dr. Russel C. Jones, NC2E Co-Chairman

SESSION I **FACULTY ISSUES** — Ballroom

2:45-6:00
Presiding: Dr. Bruno O. Weinschel
President, Institute of Electrical and Electronics Engineers

RESOLUTION TOPICS FOR GROUP DISCUSSION & ACTION:

Statement of Issues:	Dr. Gene M. Nordby
University-Industry Interaction	Dr. Leo Young & Mr. Robert W. DeSio

Discussion & Action

Attracting and Effectively Utilizing Future Faculty	Dr. Anthony B. Giordano

Discussion & Action

We Must Increase the Importance of Teaching	Dr. John D. Kemper

Discussion & Action

SESSSION I
Continued

3:45-4:00	Coffee & Soda Break	Ballroom Foyer
	How to Improve the Attractiveness of Faculty and Their Departments	Dr. George E. Dieter
	Discussion & Action	
	Session Summation	Dr. Cyril J. Tunis
	Closing Discussion & Action	
6:00-7:00	Break	Guest Rooms

* * * * *

BANQUET

7:00-9:30 and Ballroom

PRESENTATION OF THE
L. E. GRINTER DISTINGUISHED SERVICE AWARD

Distinguished Speaker:
Dr. Roland W. Schmitt
General Electric Company

Presiding: Dr. Gene M. Nordby, NC2E Chairman

Friday, November 21

SESSION II **CURRICULUM ISSUES** Ballroom

8:00-11:30
Presiding: Dr. L. S. (Skip) Fletcher
Past President, American Society of Mechanical Engineers

Background Briefing: Dr. Russel C. Jones, NC2E Co-Chairman

RESOLUTION TOPICS FOR GROUP DISCUSSION & ACTION:

Statement of Issues Dr. Gene M. Nordby

Discussion & Action

SESSION II
Continued

Industry View on Graduates-- Past, Present, & Future	Mr. James W. Poirot
Discussion & Action	
Case Study I -- Comprehensive Curriculum Revision	Dr. Jack L. Kerrebrock
Discussion & Action	
10:00-10:15 Coffee Break	Ballroom Foyer
Case Study II -- Core University Requirements	Dr. Donald McDonald
Discussion & Action	
Education's Response -- Options	Dr. Edmund T. Cranch
Discussion & Action	
Accreditation Implications	Dr. John W. Prados
Closing Discussion & Action	

LUNCHEON II

12:00-1:30 Monet Suite

Distinguished Speaker:
Mr. Louis L. Guy, Jr.
Guy & Davis Consulting Engineers
President, American Academy of Environmental Engineers

Presiding: Dr. Russel C. Jones, NC2E Co-Chairman

SESSION III **LABORATORIES, COMPUTERS AND EDUCATIONAL TECHNOLOGIES**

2:00-5:00 Ballroom
Presiding: Dr. Lionel V. Baldwin
President, National Technological University

Background Briefing: Dr. Gene M. Nordby, NC2E Chairman

RESOLUTION TOPICS FOR DISCUSSION & ACTION:

Summary of Major Conclusions of Reports — Dr. John W. McCredie

Discussion & Action

Technology's Appropriate Role in Engineering Education — Dr. Tim Healy

Discussion & Action

Resource Allocation — Dr. Gearold R. Johnson

Discussion & Action

3:30-3:45 Coffee & Soda Break — Ballroom Foyer

University-Computer Industry Interactions — Dr. Jerome Milgram

Discussion & Action

Accreditation Recommendations — Dr. Roger A. Holmes

Closing Discussion & Action

EVENING **OPEN**

8:00-10:00 NC2E Program Review Committee Meeting (Closed Session) — Ballroom A

Saturday, November 22

SESSION IV **CLOSING PLENARY DISCUSSIONS/VOTING**

8:00-12:00 Ballroom

Presiding: Dr. Gene M. Nordby
President, Accreditation Board for Engineering & Technology

Faculty Issues — Dr. Bruno O. Weinschel

Open Discussion & Resolution Voting

Curriculum Issues — Dr. L.S. (Skip) Fletcher

Open Discussion & Resolution Voting

10:00-10:15 Coffee Break — Ballroom Foyer

Laboratories, Computers and Educational Technology Issues — Dr. Lionel V. Baldwin

Open Discussion & Resolution Voting

SUMMARY

Dr. Leighton E. Sissom
Dean of Engineering, Tennessee Technological University
Chairman, The Engineering Deans Council

NC2E

National Congress on Engineering Education

Faculty Issues

Prepared by

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on Faculty Issues

Committee Members

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Dr. John E. Kemper
Dr. Allen B. Rosenstein
Dr. John B. Slaughter
Dr. Cyril J. Tunis
Dr. Leo Young

NOVEMBER, 1986

FACULTY ISSUES

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REVIEW OF RECENT REPORTS

-- FACULTY ISSUES

The following recent reports are recommended as the most appropriate references on faculty issues to be discussed at the National Congress on Engineering Education.

- Engineering Education and Practice in the United States: Foundations of Our Techno-Economic Future, Jerrier A. Haddad, Chairman, Committee on the Education and Utilization of the Engineer, National Academy Press, Washington, DC, 1985.

- Engineering Undergraduate Education, Edmund T. Cranch, Panel on Undergraduate Engineering Education, National Research Council, National Academy Press, Washington, DC, 1986.

- Engineering Graduate Education and Research, John D. Kemper, Chairman, Panel on Engineering Graduate Education and Research, National Research Council, National Academy Press, Washington, DC, 1985.

- Continuing Education of Engineers, Morris A. Steinberg, Chairman, Panel on Continuing Education, National Research Council, National Academy Press, Washington, DC, 1985.

- Education for the Manufacturing World of the Future, National Academy of Engineering, National Academy Press, Washington, DC, 1985.

The major issues and recommendations of these reports are summarized below:

1. Doctoral Fellowships (EE&P, p. 80)*

   A major increase in fellowship support and concomitant engineering college research support is needed to attract more of the very brightest U.S. citizens into graduate programs in engineering. To attract top students into graduate work, doctoral fellowships should carry stipends equal to at least half the starting salary of a new B.S. graduate.

   (Also, EGE&R, p. 57)

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*EE&P = "Engineering Education and Practice in the United States:"
EUE = "Engineering Undergraduate Education"
EGE&R = "Engineering Graduate Education and Research"
CEofE = "Continuing Education of Engineers"
EMWF = "Education for the Manufacturing World of the Future"

The number of doctoral fellowships should be increased in order to increase the proportion of U.S. citizens from the top decile of their graduating classes who enter doctoral study. About 1,000 new "starts" should be available per year, with stipends at least equal to 50 percent of the average starting salaries of graduates going directly to industry. Industry and government should work together in providing this program. The total cost per year would be in the range of $60 million to $70 million for the nation.

2. Making Faculty Careers More Attractive (EE&P, p. 81)

Increasing the supply of highly qualified U.S. residents holding the Ph.D. would help to alleviate the problem. (Restoration of the 1975-76 student/faculty ratio, however, would require even further funding of graduate programs.) Universities, for their part, must make engineering faculty careers more attractive than at present in order to fill vacant faculty positions. Salaries need further improvement, adequate facilities are necessary, and current teaching overloads should be reduced.

(Also, EUE, p. 5)

In addition to support for graduate education, engineering schools and professional societies must create and maintain an active campaign to emphasize the advantages of an academic career. Industry, government, engineering schools, and professional societies must encourage and support master's-level programs, combined B.S.-M.S. programs, and release time to enlarge and develop the pool of potential faculty.

(Also, EGE&R, p. 57)

The perception of academic life must be improved: universities must reduce the current high work loads, improve salary levels to competitive levels, and provide state-of-the-art facilities for instruction and research.

3. Using Retirees as Faculty (EE&P, p. 84, and EUE, p. 6)

Engineering faculty members and administrators should identify and utilize as faculty individuals such as government, military, and corporate retirees, with or without a Ph.D., who are not seeking tenure and who would welcome a short-term contract for a second career.

(Also, EGE&R, p. 103)

Colleges and universities should be encouraged to use adjunct and part-time faculty to enrich student educational programs. However, excessive reliance on part-time faculty can impair the quality of an educational program and should be avoided.

4. Faculty Development (EUE, p. 6)

Engineering schools must create specific faculty development programs with shared institutional, industrial, and governmental funding.

(Also, EGE&R, p. 103)

Faculty members need opportunities for self-development and self-renewal, just as do engineers in industry. Methods for accomplishing such self-renewal include participation in research, industrial consulting, sabbatical leaves, and summer jobs in industry.

5. University-Industry Interactions (EUE, p. 6)

Colleges of engineering and professional societies should promote the use of Professors of Professional Practice. This could be done by appointing either adjunct faculty or, preferably, full-time resident faculty for specific periods of time. The cooperation and support of industry in providing loaned staff are essential to achieving the educational goal of greater emphasis on practical aspects of engineering. The use in industry of regular faculty on complementary leaves would also support this goal.

(Also, EGE&R, pp. 116-117)

Closer ties between industry and engineering education should be fostered. Such ties can take many forms, such as increased industrially sponsored research; faculty consulting; industry financial support of graduate fellowships, modern equipment, facilities, and departmental expense. An especially beneficial form of industry-university cooperation is the establishment of industrial advisory councils to provide input to campus administrations and governmental bodies.

Industrially sponsored research in universities should be free of secrecy constraints and should be as general as possible so that the learning experiences of the students can be transferred to a variety of future needs.

Outside consulting by faculty members should be encouraged, provided it supports and helps improve the academic programs of the university. Consulting of a routine sort should be discouraged, as should consulting which is competitive with regular consulting organizations. However, full-time faculty members should limit their consulting and other outside activities so that university responsibilities are not interfered with.

6. Doctoral Degrees (EGE&R, p. 103)

Schools that emphasize undergraduate education can utilize many faculty who do not have doctor's degrees. Universities with

significant graduate and research programs will also be able to utilize some nondoctoral faculty in special roles. However, the faculty in such "research universities" should, in the overwhelming majority, have doctor's degrees.

7. Continuing Education (CEofE, p. 54)

Universities should reexamine the priority of continuing education programs for engineering in light of their role during the coming decade and then make a commitment to meet the responsibilities.

8. Manufacturing

(EMWF, p. 11)

U.S. industry became noncompetitive because designs were not readily manufacturable and because quality standards that were much too low were tolerated in factories.

(EMWF, p. 12)

New materials with advanced properties will displace conventional products and processes. For example, the silicon revolution in digital electronics is known to all. Monolithic gallium arsenide microwave circuits will have an equally dramatic effect in radio frequency devices over the next decade. Composite materials, including carbon fibers imbedded in resin, will change structural designs. One general aviation manufacturer has already wound a complete fuselage from carbon fiber tape in less than a day and a half.

(EMWF, p. 16)

Schooling is necessary but not sufficient. Industry must change the employment practices for manufacturing professionals, and provide both financial incentives and intellectual challenges so that better candidates will opt for careers in manufacturing.

(EMWF, p. 17)

Organizational reforms must force a closer relationship between engineering and manufacturing to develop producible designs and the restructuring of factories to reflect the systems nature of manufacturing operations. More important, manufacturers must be convinced that universities can contribute and must be willing to explore modes of cooperation.

(EMWF, pp. 18-19)

Universities must encourage better students to consider careers in manufacturing by raising admission standards and by

stressing manufacturing opportunities in high school recruiting. And, perhaps, university research can develop a stronger theoretical basis for manufacturing. What is meant by a producible design? How can achievable quality levels be estimated? Together, industry and universities can establish research programs that address problems in manufacturing technology.

(EMWF, p. 24)

Products must now be designed both with careful consideration of cost and producibility and with the participation of the entire manufacturing organization.

(EMWF, p. 49)

The engineering perspective has broken down manufacturing operations into small segments, which has tended to maximize the performance of each segment often at the expense of optimum integration of the whole manufacturing operation. This problem becomes even more severe when the interface of manufacturing with the other company functions is considered--for example, more effective coupling of both the manufacturing and market strategies into a cohesive competitive strategy.

(EMWF, p. 52)

The third requirement for achieving manufacturing excellence is to integrate functions within manufacturing organizations. In each operation at TRW, a strong partnership is built of equals--R&D, design, manufacturing, marketing, sales, and all the supporting functions working in a closely knit team to execute the unit plan. Although each of these functions has different core responsibilities, there should be no isolation.

(EMWF, p. 53)

.... the areas of expertise sought in potential faculty members are often dictated by the basic or applied research being funded. Outstanding students are then attracted to the disciplines taught by these capable, interesting faculty. Industry must therefore provide funding for manufacturing-related research and development to generate the interested faculty base.

(EMWF, p. 97)

In particular, a greater focus is needed on integration between the design end of the problem and the manufacturing (or producibility) end of the problem. This feature is generally lacking in existing conventional engineering courses.

(EMWF, p. 99)

The time frames of planning and operations are far different in industry and universities. A university typically takes the long-term view, which is appropriate to education and the search for the advancement of human knowledge. Industry, however, must focus primarily on real-time, immediate problems.

PROPOSED RESOLUTIONS

By

NC2E Faculty Issues/Resolutions Committee

INCREASING ATTRACTIVENESS OF GRADUATE PROGRAMS

Engineering students are motivated to seek a career devoted to the creation of useful goods and services. Many are not motivated by a career in science or research. Since many engineering educators have been largely selected for their research ability and tend to replicate themselves, some engineering students are turned off by a science and research oriented educational experience. Those students recognizing that most engineering graduate work is research directed find no motivation in graduate work and the faculty career for which it is prerequisite.

The development and recruitment of professionally competent graduate students and faculty would be enhanced by the selection of faculty on the basis of education for professional competence and engineering practice.

GRADUATE SUPPORT

A major increase in fellowship support and concomitant engineering college research support are needed to attract more of the very brightest U.S. citizens into graduate programs in engineering. To attract top students into graduate work, doctoral fellowships should carry stipends equal to at least half the starting salary of a new B.S. graduate.

PROFICIENCY IN ENGLISH

We recommend that the "Test of Spoken English" administered by the Educational Testing Service be required of all teaching assistants and new faculty members for whom English is a second language. A score of 250 (out of 300 maximum) is recommended as an acceptable score.

THE TEACHING FUNCTION

Universities and colleges should be diligent in maintaining the integrity and effectiveness of the teaching function. In no case should tenure be granted unless there is clear evidence of ability and effectiveness in teaching. Similar evidence should be required at each subsequent evaluation to ensure that teaching effectiveness is maintained throughout a faculty member's professional life.

WORKSHOPS FOR EFFECTIVE TEACHING

It should be the responsibility of the hiring institution to provide guidance and assistance in effective teaching by recommending and/or sponsoring appropriate seminars, workshops, or institutes. Educational institutions should offer a pre-service or in-service workshop for faculty members, including adjunct or part-time faculty.

ENGINEERING PRACTICE

Engineering schools should seek to employ faculty with demonstrated professional competence in the practice of engineering. This applies to research universities as well as to others. With the increasing tendency for industry to lead academia in some research fields, and with the increasing tendency for industry to employ engineers with graduate degrees, the need for close relationships between industry and academia becomes stronger than ever.

We recommend that, before senior faculty status is attained, engineering faculty should have accumulated a minimum of two years of experience related to the function of providing innovative products, methods, processes, or services of an advanced nature. This experience may be gained through a sabbatical in industry, a series of summer jobs, through consulting, by supervising industrially-sponsored research contracts, or some combination thereof. Familiarity with industry or with other relevant professional practice should be kept current.

BALANCED COMPOSITION OF ENGINEERING DEPARTMENTS

In building faculty within an engineering department, strong attention should be given to the balance of faculty background, attitudes and experience. The faculty composition, in addition to teaching, should address the following issues of balance: science, engineering practice; design, analysis; strong professional experience, research.

ENHANCING THE ATTRACTIVENESS OF FACULTY CAREERS

In order that the very best engineering students can be attracted to faculty positions, the quality of life of the engineering faculty member must be improved. The quality of life can be improved in many ways. The most obvious are providing the engineering faculty member with a teaching load that is reasonable, providing the faculty with time for library and computer studies, providing modern engineering experimental facilities, and competitive compensation.

MAINTENANCE OF PROFESSIONAL COMPETENCE

Just as engineering practitioners need to preserve and enhance their professional competence throughout their careers, engineering faculty members must stay current with their technical fields and with educational developments. We recommend that:

-- Individual faculty members assume the principal responsibility for arranging their own professional development.

-- Engineering college administration take the responsibility for making available structured professional development.

-- ABET develop criteria to appropriately measure and require faculty competence and faculty development.

-- Employer organizations provide developmental work assignments for engineering faculty members.

UNIVERSITY-INDUSTRY INTERACTION

In order to enhance U.S. competitivenes, we strongly endorse increased emphasis on advanced development university research projects that are cooperatively sponsored and jointly sponsored by state and federal agencies and industry. Such projects should be of a broad nature and should contribute to curriculum and faculty development.

NCQE

National Congress on Engineering Education

Curriculum Issues

Prepared by

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CURRICULUM ISSUES

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NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Computer Use in Engineering Education

Background

While the computer is generally used in engineering curricula, evidence of improvement in engineering education is spotty. The computer must be better integrated into the engineering curriculum in order to prepare, adequately, engineering graduates for the 1990's and beyond. Industry's competitive effectiveness in the international marketplace will depend upon its ability to improve productivity and to use computers to improve technical communications in the processes of design, analysis, manufacturing, and marketing. It is important that students become familiar with the use of computers for access to technical data bases, e.g., material properties, physical and thermophysical data, cost, and inventories as well as the use of computers for access to national computers and central data bases. Graduates of the future must be able to use computer resources efficiently and intelligently to enhance their productivity. Ref: (2-81)(8-64/66)

Vital to learning computer techniques is continuity of treatment. It is important that each course which follows the introductory computer course continue to utilize the computer appropriately to emphasize its importance at each level of study and to the practice of engineering. Accreditation visits still show significant numbers of faculty who are not proficient in the use of computers in their courses and the lack of the sequential reinforcing treatment as the student progresses.

Recommendation

In order to enhance engineering education through computer use, the accreditation criteria for computer use in engineering curricula should be strengthened so as to require institutions to demonstrate that computer use is an effective part of the instructional program. Faculty proficiency should be enhanced by in-house mandatory training of faculty and review of course utilization if necessary. Further, significant effort should be devoted by industry and government to assist with resources for adequate training, curricula improvement, and computer availability for all engineering students.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Manufacturing and Construction

Background

The United States industrial might, which was not severely challenged in the first half of this century, now finds in comparison to Japan and others, a dramatic shift in industrial "good health" with slippage most pronounced in the U.S. manufacturing base. Political, cultural, technical, and social reasons are given for this. Included in this reasoning is that our academic institutions are not developing the essential knowledge people, the technology, and the application understanding to be able to continue out-producing our worldwide competition. Erich Bloch, Director of the National Science Foundation, suggests promotion of university-industry cooperation and changes in university reward structure to facilitate communication across disciplines and research advances in multidisciplinary problems. And he disagreed with those who think that we simply have to apply current technology systematically, but says that "the problem is to develop a genuine science of manufacturing," one built on several engineerng disciplines as well as computer, information, and materials sciences. It is the lack of cross-functional perspectives, such as manufacturing practice related to product area or marketing and economic considerations, that is a major element missing in the knowledge brought to the job by current engineering graduates. Further, manufacturing must be enhanced as a career path by faculty emphasis and industry rewards for those who enter this work. Part of the problem is cultural since research careers have been made to sound more attractive than manufacturing. Ref: (10-17)

Recommendation

In as much as most engineering disciplines are involved in manufacturing and construction to some degree, every effort should be made to focus on the integration of design, planning, simulation, and control into all engineering curricula through required interdisciplinary coursework. Such coursework should foster the importance of interdisciplinary team efforts to solve engineering problems, particularly manufacturing and construction problems.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Basic Science Accreditation Requirement

Background

The ABET Criteria C.2.d. (1) (b) states that "the objective of the studies in basic sciences is to acquire fundamental knowledge about nature and its phenomena, including quantitative expression. These studies must include both general chemistry and general physics at appropriate levels, with at least a two-semester (or equivalent) sequence of study in either area. Also, additional work in life sciences, earth sciences, and/or advanced chemistry or physics may be utilized to satisfy the basic sciences requirement, as appropriate for various engineering disciplines."

These criteria are generally assumed by faculty, department heads, and accreditation visitors to consist of one or two courses in chemistry, one, two or three courses in physics, and occasionally a course in biology or materials science. It would appear that all too often the engineering curricular content in the basic sciences is dictated by what the chemistry and physics departments wish to offer, not what the engineering faculty feel they should have. The time has come to clarify the basic science needs of engineering curricula and the associated interpretation of the accreditation criteria by faculty and accreditation visitors.

With the advent of computer simulation, modeling, and analysis, it would seem that the chemistry needs of most curricula could be satisfied by one course. Further, the basic physics requirements could be restructured to make efficient use of the students' time, optimizing physics content which would be compatible with the various engineering disciplines -- with modern physics added for appropriate disciplines. The resulting credit hours could then be used as a basic science elective -- for biology, materials science, information science or as another physical or material science suitable to the student's area of study. More breadth is needed in the sciences, for example, to prepare for studies in biotechnology and information technology, the newest of the emerging fields to bear on engineering.

Recommendation

The accreditation criteria for the basic science area should be expanded so as to include basic science electives of the students' choice as part of the required coursework to add breadth to science coverage. Institutions should be encouraged to experiment with new science sequences to give more breadth and preparation for the emerging fields of interest for engineering applications, such as biotechnology, information sciences, geotechnology, and advanced materals applications.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Mathematics Accreditation Requirement

Background

The ABET Criteria C.2.d. (1) (a) states that studies in mathematics must be beyond trigonometry and must emphasize mathematics concepts and principles rather than computation. These studies must include differential and integral calculus and differential equations. Additional work is encouraged in one or more of the subjects of probability and statistics, linear algegra, numerical analysis, and advanced calculus."

These criteria are generally assumed by faculty, department heads, and accreditation visitors to consist of differential and integral calculus, differential equations, partial differential equations, and perhaps a course in engineering analysis. The mathematics departments often dictate the content of the courses, with proofs and theorems rather than analysis. The time has come to clarify the mathematics requirements in terms of modern engineering education, and to include subjects such as probability and statistics which is the foundation upon which quality control in all manufacturing processes is based and numerical analysis which is becoming a dominant tool form of engineering analysis in many engineering fields with engineering oriented applications.

Recommendations

The accreditation criteria for the mathematics area should be revised to ensure that students have some training in probability, statistics, and numerical analysis as part of the required sequence. Experimentation in methods of mathematics presentation, sequence of courses and coverage should be encouraged to see if more efficiency in knowledge transmission can be achieved.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

The Global Economy

Background

The hegemony in the world-wide marketplace enjoyed by the United States prior to World War II has virtually disappeared. Generally, only in products involving a very high engineering content has the U.S. maintained its preeminance. Consequently, successful competition in the world-wide marketplace will depend greatly not only upon our continued ability to produce high-quality engineers, but also to produce engineers who are, at the same time, aware of the implications of competition in foreign markets. To withstand international market pressures, increasing numbers of American companies will be induced to enter joint ventures with foreign firms. Successful prosecution of such ventures may well depend upon adequate knowledge of both the technology and the culture of the foreign partner.

Closely related, if not integral, to preparation for competition in foreign markets is the need for increased awareness of societal and economic aspects with which engineers must increasingly deal. These aspects involve such concepts as Benefit-Cost and Environmental Impact analyses and professional and product liability considerations.

Clearly competition in the world-wide marketplace has implications for the needed educational content of engineering curricula. High-quality technical education of engineers must always be the number one priority; however, a broader education is essential to maintaining a prominent position in the global economy. Ref: (1-1) (19-28, 51-68) (23-39, 53-55)

Recommendation

Engineering education programs should include an emphasis on technical areas which strongly impact the competitive posture of the United States in foreign markets. Such areas might include robotics, manufacturing processes, microcomputers, statistics, quality control, and inspection, as well as many others. Particularly important is the emphasis on those parts of the curriculum that develop creativity, innovation, systems, and design attributes in the student to develop products of quality to compete in global competition.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

The Industrial Environment

Background

Engineers are expected to function effectively in an industrial environment which is influenced by cost, finance and marketing, project management and organization, personal leadership, and interpersonal relations. Often, these factors constitute the dominate influence in determining the success or failure of a technical project and certainly determine the ability of the engineer to progress in his or her professional career.

Experienced engineers are not only typically responsible for technical aspects of their projects but also for team building, vendor contacts, budget control, and planning. New engineers may have less direct responsibility for the management of projects but must be familiar enough with common business practices to adjust to an environment in which they are a major influence. In spite of our understanding of these requirements, the engineering curricula do not insure that graduates are adequately prepared to understand, appreciate, or function in the business environment. Ref: (24)

Recommendation

Engineering programs should include, at an appropriate level, some study of engineering cost analysis, project management and organization, resource budgeting, and leadership theory and practice.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Engineering Sciences Accreditation Criteria

Background

The ABET Criteria C.2.d. (2) states that "The engineering sciences have their roots in mathematics and basic sciences, but carry knowledge further toward creative application. These studies provide a bridge between mathematics/basic sciences and engineering practice. Such subjects include mechanics, thermodynamics, electrical and electronic circuits, materials science, transport phenomena, and computer science (other than programming skills), along with other subjects depending upon the discipline. While it is recognized that some subject areas may be taught from the standpoint of either basic science or engineering science, the ultimate determination of engineering science content is based on the extent to which there is extension of knowledge toward creative application. In order to promote breadth, the curriculum must include at least one engineering science course outside the major discipline area."

While the criteria are reasonably general, most engineering curricula have succumbed to the traditional engineering program and find that there is insufficient space in the curriculum to cover all the courses desired. Each engineering discipline has unduly narrowed the engineering sciences required to those that strictly apply to that field. The narrowness of the usual requirements limit the engineers' ability to recognize problems in their work affected by adjacent fields and also to participate in an interdisciplinary style. Unfortunately, little has been done to refine the engineering science portion of the curricula. Favorite course, traditional courses, and "must have" courses preclude the optimization of that part of a curriculum devoted to engineering science. Does the engineering effectively use a student's time and give enough breadth? We have considerably narrowed the concepts of the Grinter Report of the late 1950's, and it has resulted in excessive early specialization.

There are many new educational delivery techniques, and the use of computers is prevalent. Is it not time to eliminate, combine, or restructure the engineering science courses?

Recommendation

Traditional engineering curricula should be carefully reviewed in terms of content so as to optimize existing courses and make room in the curricula for new areas. More emphasis should be placed upon breadth of coverage, particularly in the engineering sciences, to aid the student in understanding interdisciplinary concepts. Institutions should be encouraged to experiment with a variety of programs and report the results.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

The Basic Education Requirement (BERs)

Background

The BER has evolved around the concept that the educated person is one who has a broad based background which, in turn, usually means having an academic depth in Liberal Arts. Today university leaders, the provosts and presidents across the country, are developing a program review which will define what the BER should be for each academic college including engineering. The basis of the review which is relevant for engineering is that they are convinced that engineering education (via ABET criteria) is so narrow that graduates are severely limited in their ability to move about in the business world, and in addition, they are unable to advance professionally due to this narrow education base. Ability to read and to write at the level required for upward mobility is also part of this great weakness they see in engineers. As a consequence they feel that they can and will do us a great service by defining for us BERs that will provide a broadly and truly educated person with an engineering degree.

Engineering students do not understand the importance of effective communications, and most engineering curricula provide little opportunity for students to enhance their communications skills. In fact, "U.S. Corporations spend over a million dollars annually on basic-skills training such as reading, writing, and grammar" according to Training Magazine.

The ABET criteria state that "Competency in written communication in the English language is essential for the engineering graduate. Although specific coursework requirements serve as a foundation for such competency, the development and enhancement of writing skills must be demonstrated through student work in engineering courses as well as other studies. Oral communication skills in the English language must also be demonstrated within the curriculum by each engineering student."

While these criteria are reasonable, the evaluation of communication skills is limited. Joint efforts with English or Communication Departments are one alternative. Further, faculty could be encouraged to promote development of skills by integrating communication challenges into class exercises and homework. Such faculty, however, must be given proper training to enable them to thoroughly critique written reports and oral presentations, particularly those faculty whose native language is not English.

Effective communications are essential to the practice of engineering. It is the responsibility of the engineering faculty

to teach written and oral communications, by example and by direct review of student work, and to instill in the students the importance of this area.

Recommendation

The broadening courses and the communication skills courses associated with reading, speaking and writing should be studied via a task force with the goal of taking the initiative away from the Liberal Arts faculty and in determining what best makes sense for our engineering programs. We should be willing to put in place firm requirements to insure that all students do have the desired breadth regardless of the number of courses which are required.

Engineering curricula should include specific engineering courses which incorporate written, oral, graphical, and interpersonal communication skills, and these areas should be emphasized in the evaluation of student performance. It also would be useful to consider the development and implementation of English proficiency criteria as part of the admission and graduation criteria. It would be appropriate to establish an ABET study committee to review and revise the existing communication skill criteria.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Engineering Design Accreditation Criteria

Background

The ABET engineering criteria C.2.D. (3) state that "Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative) in which the basic sciences, mathematics, and engineerng science are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. The engineering design component of a curriculum must include at least some of the following features: development of student creativity, use of open-ended problems, development and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, and detailed system descriptions. Further, it is desirable to include a variety of realistic constraints such as economic factors, safety, reliability, aesthetics, ethics, and social impact. "Courses that contain engineering design normally are taught at the upper-division level of the engineering program. Some portion of this requirement must be satisfied by at least one course which is primarily design, preferably at the senior level, and predicated on the accumulated compound of the curricular components."

This section of the criteria describes not only the content of the engineering design portion of the curriculum but also indicates something about the methods of instruction to be used. It suggests that instruction in design is inherently different from the methods and content of science-oriented courses. Unfortunately, these differences do not appear to be generally understood in engineering education as one of the most frequent disagreements between ABET program evaluators and engineering faculty is whether the engineering design portion of the curriculum satisfies the ABET requirement for one-half year of engineering design. To some, the concern for an adequate quantity of design in the curriculum has overshadowed the even more important concern with the quality of design experience.

The ultimate test of an engineering education is the degree to which it has prepared the graduate to pursue an effective engineering career. A necessary part of this preparation is a significant and meaningful design experience for each engineering student with adequate preparation in other courses for this part of the curriculum.

CI-9

Recommendation

ABET should continue its current emphasis, intensifying effort if possible, on the design, innovation, and creativity requirements of engineering programs as described in the accreditation criteria. Furthermore, ABET should encourage experimentation by institutions to find better ways of teaching this emphasis. Such programs should continue to include considerations of economic factors, safety, reliability, aesthetics, ethics, and social impact. Quality of the design experience is more important than the quantity ABET requirements now being used. However, a comprehensive design experience is essential to all engineering programs since design ability, in the broadest sense, is the main attribute which characterizes the engineer from the scientist.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Increased Liberal Arts and Humanities

Background

In recent years there has been increased emphasis on the need for a broader liberal arts education for engineers. This emphasis has come from engineering management who find that a broader education is essential to successful interaction with the lay population. At the same time, many university faculties are imposing a university-wide core curriculum or general education requirements to assure that all graduates will have a broad university education. We believe that a liberal education must contain elements of five areas--mathematics, basic science, social science, humanities, and technology--and engineering programs are one of the few university programs that contain elements of all five. Although engineering programs contain nearly two years of work in areas other than technology, we may have the wrong proportions for the current demands of society. There is also a misperception by liberal arts faculty about the content of engineering programs. It is always easy to advise others that the most important information is their own area.

Clearly, the changing role of the engineering graduate warrants serious consideration of a broader general education. In view of the increased focus on a global economy, subject material in modern languages, geography, psychology, sociology, and political science would be of importance as well as coursework in the arts, music, law, and philosophy.

The ABET Criteria state that "Studies in the humanities and social sciences serve not only to meet the objectives of a broad education, but also to meet the objectives of the engineering profession. Therefore, studies in the humanities and social sciences must be planned to reflect a rationale or fulfill an objective appropriate to the engineerng profession and the institution's educational objectives. In the interests of making engineers fully aware of their social responsibilities and better able to consider related factors in the decision-making process, institutions must require coursework in the humanities and social sciences as an integral part of the engineering program. This philosophy cannot be overemphasized. Further, this subject area must include some courses at an advanced level rather than be limited to a selection of unrelated introductory courses."
Ref: (2-68, 69) (20-15 to 26) (22-41)

Recommendation

The humanities-social science component of the various engineering programs should be expanded and be more carefully monitored so that optimal use is made of this time in accord with

the criteria which require that the program "reflect a rationale or fulfill an objective appropriate to the engineering profession and the institution's educational objectives." Current needs to understand world economics should lead to positive consideration of economics, international relations, and second language courses for some students. The humanities/social sciences requirement in the ABET criteria is often a carelessly administered area, and it deserves more attention from both the engineering faculties and students. Further, engineering colleges should work closely with the liberal studies faculties to carefully choose and/or design course sequences to utilize the available time effectively.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

International Engineering Education Accreditation

Background

With the growth of international industry consortia and the international student population in engineering colleges, it is apparent that increased emphasis must be placed on evaluating the academic credentials of students educated outside of the United States. Many U.S. industries hire engineers in overseas offices, as well as in the United States. In addition, most universities admit international students without a full understanding of their engineering education background.

The ABET Annual Report includes a listing of engineering education programs accredited in Canada, and an ABET Study Committee is currently reviewing criteria for accreditation of programs in England. It may be that other countries have comparable accreditation or certification procedures, and a listing of such programs would be invaluable for both universities and industries in the United States.

Recommendation

In order to clarify the potential for international accreditation of engineering programs, an ABET study committee should be appointed to develop a plan for pursuing the establishment of international accreditation criteria.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Professional Level Accreditation Based on Non-Engineering Degrees

Background

Increasing numbers of graduate students in engineering have received an undergraduate degree in a non-engineering field such as physics, chemistry, geology, or biology. As a consequence, these students are not adequately prepared in the engineering fundamentals. Although these students may be prepared for graduate coursework in some disciplines, depending upon their undergraduate nature, they are not sufficiently conversant with broad engineering fundamentals to be termed "engineers." Yet, many of these students will become excellent engineers.

In view of the wide range of criteria used for admission to graduate schools in engineering and the breadth of engineering graduate programs available, many students with non-engineering undergraduate degrees complete their graduate degrees in engineering with little or no additional engineernng coursework above the basic graduate level requirements. Are these students truly engineers? Perhaps this dilemma could be resolved by establishing a graduate level or first professional level accreditation procedure, to assure that graduates of engineering programs are educated in the engineering fundamentals.
Ref: (8-4)

Recommendation

In order to identify the appropriateness of a Professional Level Accreditation procedure for this category, it is recommended that ABET establish a study committee to review the extent to which a problem exists in non-engineers obtaining graduate engineering degrees with limited or no education in the engineering fundamentals and develop criteria to allow them to qualify more expeditiously for registration as professional engineers.

NATIONAL CONGRESS ON ENGINEERING EDUCATION

CURRICULUM ISSUES

Academic Program Length

Background

Twenty-five years ago, many engineering curricula required 150 or more semester credit hours for graduation. As times and technology have changed and competition between engineering and non-engineering disciplines at universities has increased, there has been pressure to reduce the number of credit hours required for graduation. At the same time, however, the breadth of subject material required for engineering has increased. As a consequence, fewer and fewer students are finding it possible to graduate within the four-year period unless they attend summer school. Often it will take students an additional semester or year to complete an engineering degree. With the advent of the University Core Curricula and the increased emphasis on nontechnical subjects, it appears that maintaining a four-year engineering education program is unlikely unless major concessions are made or an additional year is added to the curriculum. These issues have been discussed in many different forums, yet such issues have not been resolved. What is the best arrangement for educating engineering students? Are the engineering education programs providing engineering training or engineering education?

Recommendation I

In view of the increased emphasis on a broad education for all students, it appears that a five-year education program will be necessary to provide sufficient breadth and depth in engineering education subjects to adequately qualify to enter an engineering career at the professional level. ABET and the engineering community should encourage the educational programs to develop a five-year program as the first professional engineering degree (approximately 160 semester credit-hours, in current measurement criteria).

Recommendation II

In view of the increased emphasis on a broad education for all university students, the number of technical subjects should be reduced in order to provide a basic engineering education program in four years. It should be recognized that graduates will be adequately prepared for many jobs, but with limited depth for true engineering applications. Those students desiring to practice engineering at their professional level would be obligated to attend graduate school to obtain their first professional degree. The four-year program would as a consequence be less specialized, delaying specialization in depth to the fifth year.

CI-13

Recommendation III

ABET should re-institute graduate level/advanced level accreditation, more carefully designed than the past experiment, to create dual level accreditation and encourage a longer period of study in a transitional era toward making a longer period of study the norm. In this way institutions are not forced to choose between levels and jeopardize their market without testing the format.

Recommendation IV

ABET should advise the National Council of Engineering Examiners that a five-year engineering education program is the minimum program that qualifies a person for entry into the profession of engineering, and by the year 1995 it will only accredit five-year programs for this purpose. These preferably should be five-year integrated programs leading to a master's degree, but properly designed programs of a "4+1" or "3+2" character would also be permissible.

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NC2E

National Congress on Engineering Education

Broad Academic Issues

Prepared by

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Dr. Russel C. Jones, Co-Chair, Program Committee

BROAD ISSUES

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NATIONAL CONGRESS ON ENGINEERING EDUCATION

BROAD ISSUES

Background

The following is a series of resolutions and recommendations on issues which were discussed by the NC2E Program Review Committee at a meeting held on October 10, 1986. These resolutions are not as extensively expounded upon as the others, but they are considered to be as important as any others and have received consensus agreement from the Program Review Committee.

***

BI-1. Limiting Programs

The high cost of education and lack of resources speak against the dilution of the finite number of competent available faculty and limited equipment by creating and maintaining a large number of engineering programs. Other professions have limited the number of programs by increasing the accreditation standards. The engineering profession has never opted for this approach. Regardless of the critics, who clain that limiting programs limits students, qualified students are always able to find opportunities for the pursuit of their education. With the facile mobility of peoples it is no longer a hardship nor a requirement that each major population center offer all possible programs. Many sociologists have found evidence of the desirability of having young people leave home to pursue post-secondary education.

Reallocating resources and faculty from some small marginal programs to a central unit where the programs would be strengthened by concentrating the funds, faculty, curricula and facilities stands as a positive step toward enhancing the quality of engineering education and lowering costs. There is not intent in this rationale to limit the number of students.

The quest for excellence requires program facilities, faculty, equipment, resources and a climate conducive to the pursuit of high intellectual accomplishment. Unfortunately, in our modern era of technology the goal of excellence cannot be obtained in a limited environment. The marshalling of disparate resources to a critical mass location is of great value in seeking quality and efficiency. Thus, the suggestion to try to concentrate efforts in a few good programs rather than in a multiplicity of small marginal offerings.

IT IS RECOMMENDED that engineering accreditation requirements be enhanced to reflect the desirability of concentrating programs in major centers of learning, thus eliminating many marginal programs, with the view to increase substantially the effectiveness of programs by increasing their faculty strength, curricula and facilities.

BI-2. Moratorium on New Ph.D. Programs

The enrollment statistics clearly indicate ample opportunities for U.S. citizens or residents to enter into doctoral programs in engineering. Foreign citizens seeking doctoral level education in engineering can also be accommodated with the present facilities. There is no crisis in offerings in doctoral programs in this country, nor is there any evidence of a need to expand pro-

grams. There is no evidence that any programs are running at full capacity nor that they intend to be oversubscribed.

IT IS RECOMMENDED that a moratorium be instituted in the formation of new Ph.D. programs in engineering.

BI-3. Moratorium on New Schools of Engineering

All data on the status of engineering education indicates a crisis situation in the number of available competent faculty to fill current vacancies, to provide the human resource capability necessary for growth, and to forestall acute predictable shortages due to retirements and deaths.

Additionally there is a dire need to refurbish and increase the capabilities of existing instructional and experimental laboratories.

Institutions' operating budgets must be equitably distributed among all institutional components. The crisis in engineering education has exacerbated the budgetary needs of the engineering component.

IT IS RECOMMENDED that in line with the above a moratorium be declared on the creation of additional schools of engineering.

BI-4. Faculty and Laboratory Requirements

The program leading to the first professional degree in engineering should allow sufficient interaction between faculty and students and sufficient individual instruction in engineering laboratories to insure the proper education of the neophyte engineer. The master/student relationship must be maintained at an adequate ratio to insure the proper preparation of a professional.

To ensure that the quality of the first professional degree is enhanced and to avoid shortcomings and narrowness in the preparation of the student it will be necessary to increase the accreditation requirements for numbers of faculty members to fulfill the mission of the program in providing adequate classroom and laboratory instruction.

IT IS RECOMMENDED that the accreditation requirements for numbers of faculty members be increased to provide adequate numbers of faculty for instruction and laboratory course work.

BI-5. Admissions Requirement

The engineering program continues to be one of the few leading to a licensed profession which is completed to an entry level within an undergraduate curriculum. In order to maintain a balance between a collegiate and a professional education, it becomes necessary that students admitted to engineering from the secondary schools be adequately prepared to move directly into the professional program. This requires that the secondary and primary schools prepare their students with the prerequisite mathematics, science, verbal and writing skills. Remedial work at the college level for entry into the engineer-

ing program should not be offered in the college of engineering, thus allowing the engineering faculty to teach in their disciplinary area at the collegiate level. Furthermore the high cost of collegiate remediation as opposed to proper primary and secondary school preparation must be avoided.

IT IS RECOMMENDED that college of engineering admission standards be set at a level that will require adequate secondary school preparation in science, mathematics and verbal skills to allow admitted students to enter directly into the engineering program without any college remediation in those subject areas.

BI-6. Licensure/Teaching

Licensure is mandated by law for professionals who deal with the safety and health of the public. Engineers are professionals and many of them are concerned with the public in areas that require licensure. Others are not and practice engineering without need of a license.

Although lincensure is not mandatory, the profession has always expressed concern with the teaching of design - the hallmark of engineering - as well as ethics and other topics that relate to licensure.

There is a general consensus that faculty members who teach design and topics related to the safety and protection of the public should be licensed professional engineers.

IT IS RECOMMENDED that faculty who teach design or topics related to safety and protection of the public be licensed professional engineers.

BI-7. Advisory Committees

Engineering education is essential for entry into the profession. Those who teach engineering as well as the institutions that offer engineering programs have an obligation to assure the students, parents and the public that they are truly preparing their students for entry into the profession. This assurance is demonstrated to a large degree by the accreditation of the engineering programs.

Further to accreditation, the institution and the faculty must be receptive to the needs of the profession in its practice. A bridge must be established between the halls of learning and the profession they serve. This bridge can be accomplished through advisory committees at both the college and program level.

The advisory committee should be composed of practicing engineers, and at least one-third should not be alumni of the institution.

The advisory committee can serve many functions, one of the most valuable is that of bringing the profession to the university.

The advisory committee should review the directions and accomplishments of the programs at least annually. They can serve as a testing ground for new ideas and approaches. The advisory committee should meet regularly, at least

once a year, and, between meetings, the members should be available to interact with the faculty and administration.

The advisory committee should provide the administration with an evaluation and advice from their perspective regarding areas that need strengthening or emphasis. The goal of the advisory committee should be one of joining with the administration and faculty in seeking to improve the program for the benefit of the students and the profession.

IT IS RECOMMENDED that an advisory committee of practicing engineers be mandated in each engineering educational unit.

BI-8. Quality Goals

Each program in engineering seeks to offer the best possible education in the discipline within the intellectual, cultural, capital equipment and other resources at its disposal. Efficiency is usually an outcome which has to wait to be measured over a period of years based on the progress of the graduates as they move through the engineering profession.

The faculty is very cognizant of research and development. It is their nature to look for improvement and to attempt different methodologies to reach positive results. Thus, changes in curricula, both in content and emphasis, are prevalent.

By their very nature, accreditation criteria are based on minimum entry requirements to the profession. In certain instances accreditation may be considered detrimental, as the programs sometimes view meeting the criteria as a goal to attain rather than a minimum to surpass.

Technological education and knowledge in the U.S. is considered second to none. Complacency may be a problem in the profession when it comes to education. The measurement of the quality of an educational program against minimum criteria never provides a ranking, nor does it show areas which could attain higher standards.

Through its various curricula-responsible bodies, the profession should develop a composite of an ideal program in each discipline. These best possible theoretical model curricula can then be offered to the institutions as goals toward which programs could strive. A careful construct is needed to avoid stifling initiative or giving a quantitative scale against which to rank program compliance. The ideal curricula should be presented as an alive set of parameters which will be revised on a cyclical basis (every three to five years) to incorporate changes in knowledge and in the technology of education. These summa cum laude curricula models should not be considered a part of accreditation nor should they be referred to in the accreditation process.

The model curricula should be offered to each of the discipline-oriented programs as added quality assessment vehicles they can employ in their own introspective analysis

IT IS RECOMMENDED that each discipline develop an ideal model program and offer this as an incentive to educational institutions in their own assessment of direction and attainment of quality goals.

References for the following three sections can be found at end of the section on Curriculum Issues.

BI-9. The University Environment and Culture

Background

Everyone expects the university to be a center of scholarship and research. As a consequence of this belief, government funding for research, and the premise that research and teaching are natural partners and compliment each other, the changes in the culture of engineering colleges has probably changed more drastically than others over the past 30 years. Engineering education has changed from a largely teaching environment with modest research programs to highly research-oriented graduate programs, especially at our leading universities but also those who seek to be classified as such. While this is not a universal change, it is probably universal in the upper tier of institutions which produce 50 percent of the engineering graduates. This direction is probably influenced as much by weak financing of the programs as by peer pressures.

While tenure, promotion, and retention policy at most institutions require proficiency in teaching, research, and service, the emphasis for a number of years has been strongly toward the research emphasis. Institutions often seem to be more concerned with how their peer institutions judge them than how the undergraduate students judge them, and that judgment is based upon their prominence in graduate and research programs. Too often dollars are directly equated to research quality by the administration. Tenure and promotion rely almost entirely on research productivity and numbers of publications in peer-reviewed journals. Good teaching is assumed to be a latent talent in each faculty member. University officials often deny that such is the case, quoting their published tenure and promotion policy. However, one may verify the true nature of the policy by talking to individual faculty members and how they react to local conditions. Their perception is quite different than the administration's. Young faculty members soon recognize the real hidden policy and assign their time to the high priority of getting publications out, often to the neglect of undergraduate teaching. This has been recognized as a general problem in universities as noted in the studies of the Association of American Colleges (20-35, 36, 37, 38, 39) and the National Institute of Education (22-51, 52 and 59, 60).

Design courses and laboratory courses have, thus, suffered. "As a result of curricular trends of the past 25 years, the strong tendency to emphasize things theoretical has resulted in the de-emphasis of things practical." (8-53) Everyone knows that excellent teaching in these areas requires excessive amounts of time compared with other activities and that there are no tangible rewards in salary, promotion, and tenure at many

universities, but no clear objectives for such programs or ways of assessing their effectiveness have been established by any of the individuals and organizations involved.

Recommendation

ABET should continue its current efforts and experiments in assessing the quality of continuing education efforts by those that request such aid. It should cooperate with engineering societies, the National Science Foundation, universities and companies in setting objectives of programs, assessing the long term benefits and effectiveness. Outside funding should continue to be sought to carry out those parts of continuing education planning and assessment that fall within the charge of ABET from the participating bodies.

BI-10. Continuing Education

Background

The needs of the individual engineer to constantly increase his/her knowledge of engineering either to prepare for increased responsibility or promotion or to perform one's present job more effectively are extensive. When one assesses the advice of industry relative to the content of the undergraduate curriculum and the deficiencies they see in the graduates of engineerng programs, it is apparent that only a part of this content can be included in formal education programs. Furthermore, the universities may not be the best place to carry out many of the suggestions. Still, during the 22-26 years after graduation, continuing increases in capability are obtained through a haphazard process of on-the-job learning, company training programs, seminars, conferences, and professional reading. The study by the National Research Council (2)(3) has found that:

1. By and large, universities as institutions have not participated extensively in this activity, and when they do, it is not given much emphasis.

2. Industrial continuing education programs are of great variety and display no consistent pattern, responding largely to the particular company's needs. Employer tuition support has been the largest source of funds for the engineers' continuing education activity.

3. Professional societies in recent years have sharply expanded their efforts in continuing education, but could do much more in designing and presenting professional development programs to their members. There is a lack of information on members' needs and the extent of current activities.

4. The highest demand is for highly targeted short courses that focus on new and developing technologies.

5. Methods of evaluating continuing education are not consistent and have not been designed to examine benefits that accrue to the company sponsoring or supporting the programs.

6. The engineers can work productively over a longer period if they have access to continuing education.

7. Quality continuing education programs are essential to increasing national productivity.

8. The need for continuing education is recognized by all involved--individuals, companies, professional societies, and

institutions. Relationships with professional societies, who govern ABET, have suffered, and more stringent criteria have been invoked to insure proper coverage from their point of view (8-53). It is apparent that the character of the various faculties is changing rapidly away from the practice of engineering and their traditional view of providing an introduction to the experiences they will meet in industry.

Undergraduate education probably needs to be a compromise between industry needs, directional guidance from the professional societies, and the institutions' goals. Industry needs to participate more directly with ABET, professional societies, and the institutions to make their needs known. However, they should recognize that the institutions cannot turn out graduates which have the entire body of knowledge they need for a lifetime of engineering practice. It is industry's and the individual's responsibility to have a professional development plan to complete the education for which the university has just provided a foundation.

This has lead to the NRC recommendation that, "Colleges of engineering and professional societies should promote the use of Professors of Professional Practice. Such appointments should be . . . preferably, as full-time resident faculty for specific periods of time." Loaned staff from industry, adjunct faculty, and complimentary leaves between institutions and industry are also mentioned (8-53, 54).

Recommendation

ABET should carefully monitor the teaching of the design, laboratory, and the practical aspects of engineering programs and the qualifications of the faculty who teach these courses. Quantity and quality of the experience in these areas and the attitudes of the faculty toward the practice of engineering are particularly important. Also, ABET should strongly recommend to institutions that they seek a proper balance between teaching, research, and service in their tenure and promotion criteria toward satisfying the needs of the profession as expressed by industry, professional societies, and the societal needs. ABET should continue to seek strong industry participation and also participation from our leading research institutions.

BI-11. Competitiveness

International competition is the by-word in today's industrial market place and in the economic market. The economy of the U.S. after 100 years of hegemony is faced with international competition that does not augur well for the country.

Industry has learned the lesson that increased productivity sans quality is not a solution to the economic problems. The proper use of technology will restore our economic balance, and engineering is the key to productivity.

Industry is looking at engineering schools as a source of quality professionals to add to its engineering workforce; high-quality, competent graduates are needed at all levels. The engineering academic institutions are also to provide sophisticated Reseach & Development that will aid industry, provide continuing education and, in general, assist industry in responding to the challenge.

To meet these challenges and become competitive, a major commitment of resources will be needed to carry out the following:

a) provide assistantships and fellowships with competitively attractive stipends to entice a larger share of our capable U.S. students to continue their education through graduate school to fill the pipeline providing doctoral graduates;

b) provide laboratory equipment for both teaching and research, provide computers and facilities, modernize and refurbish the teaching and research environment of engineering schools;

c) provide adequate and increasing budgets for schools of engineering, reflecting the increased size of enrollments and the need to maintain competitive salaries for faculty and increased support staff, as well as maintenance and replacement of equipment. Maintain within the institutions an environment comparable to that of leading-edge industry.

Additional governmental, private, and industrial resources will be needed to restore American competitiveness through engineering. The scale of this committment is comparable to some past efforts, such as (1) the National Defense Education Act in response to Sputnik; (2) the IBM initiative to stimulate Manufacturing Engineering programs; (3)the North Carolina Microelectronics Center; (4) the Exxon doctoral fellowship program aimed at attracting American students to engineering school facilities; (5) the Department of Defense Laboratory Equipment program; and (6) many others of lesser amounts and involvement.

The present need is far more demanding than a combination of all those mentioned. However, relying on the initiative and the commitment of industry, and the profession and the educational establishments working together, a solution at a profitable level for all concerned with long range positive benefits can be found.

IT IS RECOMMENDED that steps be taken through major resource support to the engineering educational enterprise to restore economic competitiveness to the U.S. in the international arena.

National Science Board Resolution

This National Congress on Engineering Education commends the National Science Board for its report on Undergraduate Science, Mathematics, and Science Education and strongly supports its conclusions and recommendations. Further, it endorses the Workshop on Engineering recommendations on directions for carrying out the improvements in engineering education. We agree that serious problems, especially problems of quality, have developed during the past decade in the infrastructure of college-level education in the United States in engineering. There are deficiencies in laboratory instruction, design, and innovation instruction and other areas. In the 1985-86 accreditation cycle, only 28 percent of the programs examined by ABET achieved the maximum accreditation period. This has dropped from its traditional level of 55 percent prior to 1980. At the same time the "not-to-accredit" and "probationary" actions doubled to 21 percent. This is but one indicator of the deterioration of the quality of undergraduate engineering education.

In 1982 support for educational efforts dropped to zero from its traditional 25 percent of the National Science Foundation (NSF) budget. We vitally need the leadership of the NSF to aid in the improvement of undergraduate engineering education. While the funds recommended are far from that necessary to solve all the problems of engineering education, we believe that NSF funds will be the catalyst for institutions, states, and industry to join with NSF in solving the current problems. Thus, the funds will be multiplied many fold.

The need is urgent if the United States is to maintain and improve its ability to compete in the world marketplace. Engineering is the keystone to innovation, product development, and improved manufacturing processes in every industry. We have the confidence that the United States can recover its reputation for quality with our own citizens as well as in the community of nations with some stimulation from the right sources. The engineering profession, represented by the 23 engineering societies, with over a million members, which constitute the consortium known as ABET to oversee the quality management in engineering education, calls upon the NSF, the President of the United States, and the Congress to carefully analyze the need and support engineering education improvements at this time. The need is urgent! Ref: (1)

NC2E

National Congress on Engineering Education

Issues on Laboratories, Computers, and Educational Technology

Prepared by

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NOVEMBER, 1986

SESSION ON LABORATORY
COMPUTER AND EDUCATIONAL TECHNOLOGY ISSUES

November 21, 1986
Friday afternoon

Topic	Presentor	Duration	Page No.
1. Introduction	L.V. Baldwin	5 minutes	1
2. **Summary of Major Conclusion of Reports:**	J.W. McCredie	15 minutes	1
- Recommended Reports			1
- Key Conclusions			2
3. **Major Issues and Recommendations:**			6
- Introduction		10 minutes	6
3A. - Appropriate Role of Technology in Engineering Education	Tim Healy	15 minutes	6
Discussion	L.V. Baldwin		
3B. - Resource Allocations	G.R. Johnson	15 minutes	7
Discussion	D.A. Sangrey	10 minutes	
3C. - Current Approaches to the Use of Computers in Engineering Education	J. Milgram	10 minutes	8
Discussion	D.A. Sangrey	10 minutes	
3D. - Accreditation Recommendation	R.A. Holmes	20 minutes	9
Discussion	L.V. Baldwin	40 minutes	
"Strawman" of ABET Criteria for Laboratory and Computer Experience			10
		2.5 hours Total	

SUMMARY OF MAJOR CONCLUSIONS OF REPORTS:

Introduction

Two of the most important arguments for the use of modern technology in the classroom and the laboratory are:

1. Students will subsequently use this technology in industry as an engineering tool;

2. Modern, highly sophisticated computers and computer-based instrumentation open up extraordinary new opportunities for the teaching of many aspects of engineering, covering the whole rang from fundamental concepts to applications. Modern technology can significantly enhance educational productivity in many ways including:

   - Taking over time consuming, tedious tasks such as graphing and repetitive calculations thereby increasing the time available for the intellectual part of the work.
   - Setting up of multiple "what-if?" environments which can be powerful teaching aids.
   - Providing increasingly sophisticated and effective visual data presentation.
   - Extending the range of possible student laboratory experiments to include activities that would otherwise be too difficult or too time consuming.
   - Bringing together experimentation with theory, analysis and simulation in ways that make teaching of all the elements more effective.

   The opportunities are unlimited.

Recommended Reports

The following seven recent reports summarize extensive studies of the general state of engineering education in the United States. Each has several significant recommendations that deal with the use of educational technology and university-industry interactions.

1. "Engineering Education and Practice in the United States: Foundations of Our Techno-Economic Future", National Research Council, National Academy Press, 1985 (NRC).

2. "Report of the NSB Task Committee on Undergraduate Science and Engineering Education to the National Science Board," NSB-86-100, National Science Foundation, March 20, 1986 (NSB).

3. "Report of the Task Force on Use of Educational Technology," Quality in Engineering Education Project, American Society of Engineering Education, 1986 (QEEP-1).

4. "Report of the Task Force on Continuing Professional Development," Quality in Engineering Education Project, American Society of Engineering Education, 1986 (QEEP-2).

5. "Report of the Task Force on the Undergraduate Engineering Laboratory," Quality in Engineering Education Project, American Society of Engineering Education, 1986 (QEEP-3).

6. "Quality of Engineering Education II," Committee on the Quality of Engineering Education, National Association of State Universities and Land-Grant Colleges, January 15, 1986 (NASULGC).

7. "Engineering Education Problems: Laboratory and Computer Equipment," A Comprehensive Study Conducted By the Professional Engineers In Education, Practice Division of the NSPE (to be published in 1986) (NSPE).

Key Conclusions

The most important conclusions concerning educational technology and university-industry interactions from these reports are presented below. The wording used is from one of the reports (the first reference). The other references point to similar conclusions in other reports (e.g., NRC/81 means page 81 of the National Research Council report). Primary conclusions (Ci) are grouped with corollaries (i.j).

C1 Computers, and computer-aided instruction in particular, should be recognized as powerful educational systems tools. These tools should be applied as rapidly and as fully as practicable in all academic programs in such a way as to enhance the quality of engineering education. Engineering schools should be encouraged to create programs for development of educational technology by faculty with shared institutional, industry, and government funding (NRC/81, QEEP-1/50, NSB/86).

1.1 Each engineering school and its university must have a coherent strategy for conversion to broad based use of computers, and their integration into a campus-wide communications network (QEEP-1/50, NRC/118).

1.2 Each engineering school and its university should have a coherent plan for the development of use of video courseware to supplement faculty members in the classroom and to facilitate delivery of courses to off-campus locations (QEEP-1/51).

1.3 Each college and university must have a comprehensive strategy for campus-wide communications systems, including the characterization of its voice, data and video requirements (QEEP-1/51).

1.4 The practically mandatory use of the computer as a learning tool in both the classroom and laboratory has required that over 50% of all equipment expenditures be allocated to computer hardware and software (NSPE,4).

C2 More financial resources need to be provided to engineering schools and their universities for the implementation of educational technologies from sources such as government, industry, and reallocations within the universities themselves (QEEP-1/52, NSB/71, NSB/79, NRC/82).

2.1 In the last several years, there have been significant increases from state budgets and increases in donations of equipment. However, maintenance budgets have not kept up with these increases. It is recommended that tax deductibility be provided for maintenance of donated equipment, to encourage industry to provide maintenance along with the gift. Further, it is recommended that university administrations provide maintenance budgets that will be compatible with equipment budgets so that provisions for maintenance are included at the time of purchase. The increases in equipment budgets are welcome but still far from adequate to satisfy "catch-up" needs as well as continuing needs (NASULGC/13, QEEP-1/54, NSPE,17).

C3 Closer ties should be fostered between university and industry. Creative and innovative ideas along the lines of the Semiconductor Research Corporation and the NSF's Engineering Research Centers are invaluable. In addition, current programs of industry-sponsored research, advisory councils, shared faculty, industry financial support for equipment and facilities, and joint industry-university provision of continuing education should all be encouraged. Continuation of the R&D tax credit is essential for maintaining all forms of industry support for research in engineering schools (NRC/82, NSB/67&71, QEEP-1/54).

3.1 Employers of engineers, both industry and government, should:

- o provide developmental work assignments to engineering faculty for temporary, full-time periods;
- o make some of their specialized facilities available to students and to faculty; both students and faculty will gain experience and competence with modern engineering equipment;
- o make appropriate employees available for short periods of time to lecture, teach or conduct seminars on engineering college campuses (QEEP-2/15).

C4 In seeking to describe the characteristics of excellent laboratory programs, the objectives that are held for these programs are important. Using expected student learning as the basis, several goals and objectives for the undergraduate engineering laboratory can be articulated.

1. First, the students should learn how to do experimental work expected of engineering professionals in the discipline.
2. Second, the laboratory can be a place for the student to learn new and developing subject matter.
3. Third, laboratory courses help the student to gain insight and understanding of the real world including valuable preparation for working as part of an engineering team.
4. Fourth, the laboratory can provide an opportunity for the development of the student's ability to communicate effectively.

The ability to conduct experimental work includes planning experiments when an experiment is appropriate. The analysis of experimental data and the assessment of experimental work of others are other capabilities students should expect to learn. With guidance, students should recognize that the undergraduate laboratory is a unique opportunity for learning about engineering, for learning about some of the work engineers do, and for gaining new insights to the topics covered in lectures, textbooks, and discussions. Faculty members must demonstrate that they understand the wholeness of engineering, and prospective employers must demonstrate that they expect engineering graduates to be ready to deal with problems that involve real processes and products (QEEP-3/2).

4.1 The enthusiasm, capability and interest of the faculty members involved in teaching laboratories are among the most significant factors for a successful laboratory program. Even so, it appears that this fact has not been given adequate recognition. Thus, a current problem of laboratory instruction is how to involve the most competent faculty members in laboratory instruction and recognize them for their efforts. It hardly seems necessary to comment that qualified, interested staff are necessary to the success of an undergraduate laboratory program, yet this fact seems to have gone unnoticed for far too long. (QEEP-3/12)

4.2 Although many recognize that this situation exists, all appear to feel helpless to make any changes because of lack of faculty, faculty loading problems, university policies for faculty recognition, publication and research policies, and a lack of conviction concerning the importance of the undergraduate laboratory program. These factors, either individually or in combination, appear to relegate the undergraduate laboratory to a second-class statue. (QEEP-3/13)

4.3 The fundamental nature of the academic reward system has resulted in a loss of priority for excellence in undergraduate laboratory instruction. The time required for laboratory course preparation and teaching is not valued at the same rate as time spent in traditional classroom teaching or as time devoted to research. In addition, excellence in laboratory teaching and dedication to this task is often not recognized in proportion to the apparent importance of the undergraduate laboratory in the overall education of engineering students. One consequence of this lack of commitment is that those responsible for laboratory instruction are often unaware of the industrial situations and requirements for which students are being prepared. (QEEP-3/13)

MAJOR ISSUES AND RECOMMENDATIONS:

Introduction

This presentation will focus on issues which are debatable. We will first discuss the appropriate role of technology in engineering education. To frame the broad issues, we summarize with four guiding principles. Next we examine recent trends in resource allocation in engineering education for laboratories and computers. There is a revolution underway here, rapid change with many opportunities to improve the instruction of students. Three recommendations summarize this section. Next we will highlight current approaches to the use of computers in engineering education. The discussion will solicit your views of the relative importance. In conclusion, we frame an accreditation recommendation to ABET and the founding societies.

Appropriate Role of Technology in Engineering Education

Addressed to Faculty and Academic Administrators

1. The teacher must continue to be the primary focus of the educational activity, but today's technology should be used to enhance the teaching process by giving the teacher new tools for calculation, for simulation, and for display.

2. Laboratory experience is a vital component of engineering education with a sound pedagogic foundation and clear relevance to successful practice. It should be a component of every undergraduate engineering program. A variety of modes for laboratory instruction is being used, and should be encouraged. Computer-based simulation can be combined effectively with direct experimentation in such programs.

3. The conventional library has long been recognized as as essential resource for the student. The collection, delivery and processing of information using today's technology is a powerful new resource which must be made available to the student in as broad and diverse a form as possible.

4. More than even before, the education of the engineer must be a lifetime process. This requires techniques and skills which are necessary for the effective use of continuing education. The needs of the mature individual to maintain competence as well as to focus on a new area of study should be anticipated in undergraduate education. Educational technologies such as instructional television (ITV) and combination of television and computers should be introduced to undergraduates because these show great promise in assisting life-long study.

Resource Allocations

Addressed to:		
Industry	1.	Industry is urged to continue its financial support for laboratory and computing equipment. Recent marked improvements in these areas of engineering education reflect the growth of this support.
Academic Administrators and Leaders of Computer Industry	2.	Cooperative efforts should be made to develop new approaches for maintenance of computer hardware and software, otherwise the task probably cannot be accomplished.
Academic Administrators and Leaders of Industry	3.	Laboratory equipment donated by industry can be an important source which has not been exploited to the degree recently experienced with computers. Efforts should be directed to improve utilization of major lab facilities on a regional basis.

Current Approaches To The Use of Computers in Engineering Education

The modern digital computer has been widely discussed as having enormous potential for delivering educational services. The state of the art in computer technology has evolved rapidly since its initial development in the 1940's, with costs of computation declining roughly 30 percent per year. There is no reason why these historical cost declines should not continue for the next decade.

This means that the computer, particularly the personal computer, may well prove to be one of the most profound changes in educational technology.

At the current time, the enormous diversity of hardware and software systems places educational institutions in a difficult position. Many institutions are virtually paralyzed by the potential problems associated with adopting incompatible computational technologies, and are deeply concerned with the short useful lifetime of investments in hardware and software. While it would be useful for educational institutions to have a very limited set of compatible, long-lived computer options, it is unlikely that this will happen in the foreseeable future. Educational institutions will have to cope with the diversity in computer hardware and live with the rapidly changing computer environment. (QEEP-1/16)

This presentation will highlight the:

- Computer as Simulator of Complex Systems
- Computer as Laboratory Instrument
- Computer as Virtual Laboratory
- Computer as Tutor
- Computer as Textbook
- Computer as Blackboard
- Computer as Special Purpose Learning Environment
- Computer as Communications Medium
- Computer as Mediator
- Computer as Recreation

Discussion will focus on the pros and cons of the various approaches.

Accreditation Recommendation

Should ABET have minimum criteria for laboratory and computer experience in undergraduate engineering education?

Pros	Cons
Minimum requirements for set by engineering societies	Another accreditation constraint
Quality judgment standards established by societies	Stifles freedom to try totally new approaches
Define several classes of acceptable lab/computer experience - specify mix	May call for difficult investment in resources
Situation is not presently good in all schools - need to pull up some to minimum standards.	Things are done well now - Why change the rules?
May lead to a broadly accepted norm of lab and computer experience for the undergraduate	We have a good program now but it doesn't meet the new criteria
Can be used to require direct faculty participation and administrative recognition of faculty lab efforts	Requires a search for consensus in a complex subject
	Not enough time during an ABET visit to really check into lab/computer matters thoroughly

Conclusion: We feel the pros outweigh the cons and agree with the recommendations of the "QEEP" executive summary: on minimum requirements for, and recognition of faculty time required for laboratory and computer experience in undergraduate engineering education.

"Strawman" of ABET Criteria
for Laboratory and Computer Experience"

Criteria - Laboratory and computer experience is a valuable part of engineering education. Evidence of program commitment to this principle consists of the following:

1) curricular requirements for a mix of several forms of laboratory and computer experience at or above the levels described below;

2) availability of appropriate equipment and space resources to meet these requirements; and

3) assignment of responsibility for the provision of laboratory and computer experience to both junior and senior faculty.

Laboratory and computer experience can be provided in several forms. The total experience of an engineering student should include elements from each of the forms given below.

a) Engineering Science Labs - These are customarily structured laboratory courses that help the student to gain physical and mathematical insight into engineering principles. They support and draw from classroom work in the engineering sciences and introduce the student to elementary measurement methods and tools of the engineering professions. Written reports should concentrate on brevity and graphics as a descriptive shorthand. Simple yet elegant concept experience and illustration with conventional professional equipment is the goal.

b) Basic Simulation and Modeling - These are series of computer-based short projects associated with engineering science course work that either simulate physical or mathematical behavior of a system or model a system from experimental data. Written reports should concentrate on well-documented programs and clear graphics or tabular presentation of results. Development of simulation and modeling skill is the goal.

c) Engineering Professional Labs - These are structured lab courses associated with engineering design and advanced engineering professional coursework. Experience should include integration of engineering concepts with substantial and extended work in engineering design, test, and evaluation. Use of modern professional equipment and computer-based data acquisition and analysis is an important part of the professional nature of such lab work and should be emphasized. Written and oral reports should be of the character given to a client who might pay for such work and should reflect the desirably high quality of the client-engineer professional relationship. Experience in the

nature and methods of professional experimental engineering work is the goal.

d) Professional Simulation and Modeling - These are computer-based projects of a substantial and extended nature associated with engineering design and advanced engineering professional course work. It is most desirable that such simulation and modeling be linked to Engineering Professional Lab work. Moreover, it is most desirable that this simulation and modeling make use of major engineering analysis and design applications programs widely available and in use in the engineering profession today. General familiarity with the ease of use and power of commercially available applications programs is the goal. Written reports should be in the form of standard outputs of such programs and succinct descriptions of the actual applications.

Discussion - Elementary engineering freshman design and introduction to engineering course lab work may qualify for engineering science lab or basic simulation and modeling credit. Engineering CAD courses may qualify for basic simulation and modeling credit.

Bachelor's degree theses, structured co-op work experiences with written reports judged by faculty as well as industrial advisors, and independent study projects culminating in written reports and formal evaluation may qualify for engineering professional lab or professional simulation and modeling work. At all times, the technical reports and presentations should be evaluated on both technical content and clarity.

Guidelines - The member societies of ABET will determine individual minimum guidelines for the quantity and quality of undergraduate laboratory and computer experience in their respective professions. These individual society guidelines should meet and may exceed these ABET criteria:

1) Undergraduate engineering laboratory and computer experience should consist of a minimum of the equivalent of one-fourth of a year or 6.25 percent of the total semester credit hours required for the baccalaureate degree. Use the appropriate conversion factors for a quarter system program.

2) This minimum experience should contain at least one of each of the four forms of experience described above. The specific mix beyond this requirement is the choice of the individual program except where member societies rule differently.

Member society guidelines in addition to the above will be widely published and available to educational institutions at least four

years prior to requirements for curricula to meet such society guidelines.

> (In a related but separate publication, member societies should develop and keep current goals of excellence to guide the development of laboratories and computing facilities).

The availability of the appropriate equipment and space to meet the laboratory and computer experience requirements is based on the judgement of the individual ad hoc society visitors to a program. It is important in this judgement to evaluate what the individual student actually experiences. Fine equipment may be at hand in the educational institution but not be available to the undergraduate on a regular basis; equipment may not be available in the institution but readily available in co-op industry. Open scheduling of labs or computers may greatly increase the general availability of space and facilities with relatively modest resource investment.

The provision of the laboratory and computer experience opportunities for the undergraduate engineering student is the responsibility of both the junior and senior faculty. Because the time demanded of faculty for the provision of quality lab and computer experience usually exceeds that demanded for the provision of an equivalent amount of classroom course material, it is necessary that academic administration policies recognize, support and adequately reward a strong commitment to laboratory development and maintenance. This commitment should be evidenced in direct faculty design and development of instructional materials and direct faculty supervision of laboratories or close faculty supervision of teaching assistants assigned to laboratory duties.

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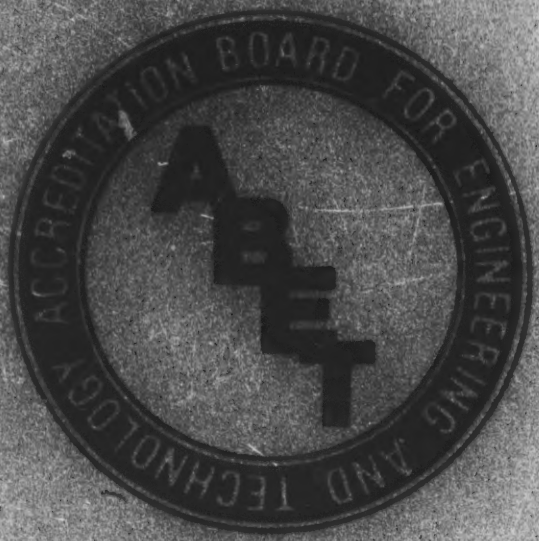

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